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PHYTOPATHOLOGY

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THE RUST OF COWPEAS

F. D. Fromme[1]

With Plate I

In a previous paper[2] the writer, together with S. A. Wingard, briefly discussed a rust of the cowpea (*Vigna sinensis* (L.) Endl.) which was found to be distinct in pathogenicity from the bean rust (*Uromyces appendiculatus* (Pers.) Fries to which it has commonly been assigned. Additional study of the cowpea rust has shown that it is distinct in morphology from the bean rust, as well as in pathogenicity, and it is presented herein as a clearly defined species.

MORPHOLOGY

The most distinctive feature is found in the location of the urediniospore germ-pores; a character of marked taxonomic value which has been used extensively by Arthur and other workers in his laboratory.[3] The urediniospores of *U. appendiculatus*, according to Arthur's description in the North American Flora, show 2, rarely 3, equatorial pores. My study of the species on kidney bean confirms this as to location of pores. They are invariably in the equatorial zone and are always 2 in number (Fig. 1, B; Pl. I, fig. 2). I have seen no spores, however, in which 3 pores could be clearly distinguished. The urediniospores of the cowpea rust also show 2 pores but their position is distinctly superequatorial (Fig. 1, A; Pl. I, fig. 1). They are more distinct than are those of bean rust and are often seen in the untreated spore; they are clearly visible after treatment with lactic acid. The pores of bean rust are not easily seen except after treatment and then, as a rule, only when the spore is

[1] Paper 60 from the Department of Plant Pathology, Virginia Agricultural Experiment Station.

[2] Fromme, F. D., and S. A. Wingard. Varietal susceptibility of beans to rust. Jour. Agr. Res. **21**: 385–404. 1921.

[3] Arthur, J. C., and F. D. Fromme. Taxonomic value of pore characters in the grass and sedge rusts. Mycologia **7**: 28–33. 1915.

in such a position that the pores appear in the side walls. This difference in visibility is probably due to the darker wall of the spore from cowpea. A slight distinction is also seen in the surface markings of the spores; the echinulations are closer and less prominent in the cowpea rust than in the bean rust. The uredinia on the cowpea are darker in color and larger, as a rule, than those on bean (Pl. I, fig. 3).

The teliospores are very similar (Fig. 1, A and B), but those from cowpea usually show a slightly thinner side wall and less apical thickening; they are also of the lepto or non-resting type, a point that will be discussed later, while the teliospores of bean rust apparently require a considerable after-ripening period before they are capable of germination.

The aeciospores of the two rusts are indistinguishable (Fig. 1, A and B) but the arrangement of the aecial groups is distinctive. Fisher[1] describes the aecia of *U. appendiculatus* as often in "kreuz formige" groups and this is true of the aecia on Phaseolus seen by the writer. The groups suggest crosses (Pl. I, fig. 4) or rosettes (Pl. I, fig. 5) according to the number of aecia. The aecial groups are small, the average number of aecia to the group being 7 and the range from 4 to 12. This grouping has not been seen in the cowpea rust. The aecia here are in the usual annulate group on slightly raised areas (Pl. I, fig. 6). The groups are considerably larger than are those on bean and they average about 50 aecia to the group.

The presence of superequatorial pores in the rust of Vigna has been noted by Arthur,[2] but at that time he apparently considered this a varietal distinction rather than a specific one. In a discussion of material on *Vigna repens* and *V. vexillata* from Porto Rico he writes:

> While the pores in the urediniospores of this species are usually two or three, and equatorial, they are sometimes four in number and sometimes are distinctly superequatorial. The Stevens' collections from Porto Rico show only uredinia, and the spores are 2-pored. On Phaseolus the pores are mostly equatorial, but on Vigna they are markedly superequatorial.

He makes a similar comment in a later paper[3] as follows:

> The collection on *Vigna vexillata*, made by Mr. Johnston, shows urediniospores with two or three pores, varying from equatorial to markedly superequatorial, a condition also noted in the Porto Rican rusts on this host genus. The species is autoecious, but

[1] Uredineen der Schweiz, p. 19.

[2] Arthur, J. C. Uredinales of Porto Rico. Mycologia **7**: 185. 1916.

[3] Arthur, J. C. Uredinales of Cuba. Memoirs Torrey Bot. Club **17**: 129. 1918.

the pycnia and aecia have not been reported from the tropics, and even telia are somewhat rare. The rust is cosmopolitan on Dolichos, Phaseolus, Strophostyles, Vigna, and probably other genera.

SYNONYMY OF COWPEA RUST

The foregoing treatment of the cowpea rust is that commonly followed; it is referred to *U. appendiculatus* in all taxonomic treatments of this species seen by the writer and commonly passes under this name in current literature. There are, however, eleven rust species which have been described on species of Vigna. Four of these are species of Aecidium, two species of Uredo, and five species of Uromyces. They are listed in the following:

Aecidium vignae Cooke, on *Vigna marginata*, Natal, South Africa, Grev. **8**: 71. 1879; *A. nigro-cinctum* Pat. & Har., on *Vigna sp.*, French Indo-China, Bull. Myc. Fr. **22**: 116. 1906; *A. caulicola* P. Henn., on *Vigna sp.*, Dembo, central Africa, An. Mus. Congo **2**: 95. 1907; *A. decipiens* Syd., Monog. Ured. **4**: 223. 1923.

Uredo purpurascens P. Henn., on *Vigna sp.*, central Africa, An. Mus. Congo **2**: 93. 1907; *U. vignae* Bres., on *V. lutea*, St. Thomas, West Indies, Rev. Myc. **13**: 66, for 1891.

Uromyces vignae Barcl., on *Vigna vexillata*, Simla, India, Jour. Asiat. Soc. Bengal **60**: 211. 1891; *U. pazschkeanus* P. Henn., on *Vigna sp.*, Abyssinia, Bull. Herb. Boiss. **1**: 107. 1893; *U. vignicola* P. Henn., on *Vigna sp.*, Africa, Eng. Bot. Jahrbr. **38**: 103. 1905; *U. punctiformis* Syd., on *V. strobilophora*, Mexico, Ured. 1513, 1901; *U. vignae luteolae* P. Henn., on *V. luteola*, Africa, An. Mus. Congo **2**: 95. 1907.

Only two of these species, *U. vignae* Barcl., and *U. vignae luteolae* P. Henn., can be assigned with any degree of certainty to the rust of cowpea under discussion. Although the writer has seen no material of Barclay's species there can be little question as to its identity. The type collection was made near Simla, India, on *Vigna vexillata* (L.) A. Rich.,[1] a cosmopolitan species which is represented in the Arthur herbarium[2] by three rust collections, two from Cuba and one from Porto Rico. These have been examined and found identical with the rust of *V. sinensis*. Barclay describes the urediniospores of *U. vignae* as:

[1] It is to be noted that Barclay cites the host as *V. vexillata* Benth. but Richard's name antedates this. The two refer to the same species.

[2] The writer is indebted to Dr. J. C. Arthur and to Purdue University for the loan of herbarium material, and also to Dr. Arthur for critical reading of this manuscript.

Brownish red, oval to round, thin walled, very spiny and with a few immature teleutospores among them. They measured when fresh and just wetted 26–29 × 19–18 μ. The teleutospores are deep brown, oval, very deciduous, with a portion of colourless stalk adherent, with a pale-brown, shallow mammila, and a smooth surface. The fresh spores just wetted measured 35–27 × 22–20 μ. The portion of adherent stalk measured up to 40 μ in length.

The close similarity of these measurements with those of the species under discussion leaves little doubt as to their identity. It seems probable also that *U. vignae luteolae* is identical with this species as it is listed by Sydow as synonymous with *U. appendiculatus* to which he also assigns the rust of *V. sinensis*.

None of the species of Aecidium described from Vigna can be placed with any certainty and probably none of them relates to the rust in question. *Aecidium caulicola* has small aeciospores, 10–15 μ according to Hennings, and *A. vignae* has aecia in large groups on strongly hypertrophied areas of the leaf blade and petiole.

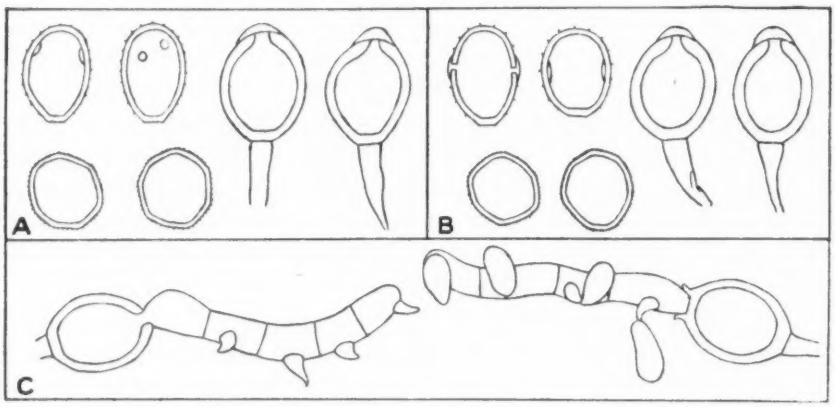


FIG. 1. A. Aeciospores, urediniospores and teliospores of *Uromyces vignae* from *V. sinensis*. The urediniospores show 2 superequatorial pores. B. Aeciospores, urediniospores and teliospores of *U. appendiculatus* from *Phaseolus vulgaris*. The urediniospores show 2 equatorial pores. C. Germinating teliospores of *U. vignae*.

Uredo vignae has been transferred by Arthur (Bull. Torrey Club **44**: 509. 1917) to Phakopsora, a genus in which the uredinia are bordered by a delicate cellular peridium, and *U. purpurascens* has small urediniospores.

The urediniospores of *Uromyces punctiformis* are thin walled with 2 inconspicuous, approximately equatorial pores, and are readily distinguished from those of *U. vignae*. The telia of this species are minute and the teliospores are punctate and have long pedicels. Arthur has placed it under *U. appendiculatus* (N. Am. Flora **7**[3]: 257. 1912) but it appears to the writer to be a valid species. It is known only by the type collection. *U. vignicola* although described as a rust is said to be a Synchytrium. The status of *U. pazschkeanus* is in doubt. According to Sydow the teliospores are distinguishable by thick pedicels which swell in water. No urediniospores are described. A specimen which comes from the region of the type, collected by G. Schweinfurth on *Vigna sp.*, Eritrea, Akrur, February 14, 1894, and labeled *U. pazschkeanus*, shows urediniospores 20–22 × 23–27 μ, with 2 superequatorial pores, and is identical with *U. vignae* in other respects. The specimen may be incorrectly named, however, and it seems best to leave the assignment of this species open for the present.

A critical examination of material previously listed under *U. appendiculatus* shows the following to be additional hosts for *U. vignae:—Dolichos lablab, Phaseolus truxillensis, Vigna repens* and *V. sesquipedalis*. A point of unusual interest is found in the occurrence of both species on *Dolichos lablab*. *U. vignae* occurs on two collections of this host from Cuba, as cited later under hosts, and on one from India, while a collection from Jamaica, lower slopes of Mt. Moses, April 14, 1903, L. M. Underwood, and one from Krakau, Bot. Garden, August, 1891, M. Raciborski, both bear rusts readily identified as *U. appendiculatus*. All material seen on the other hosts of *U. vignae* as listed is referable to this species. The occurrence of *U. vignae* on *Phaseolus truxillensis* is somewhat surprising in view of the fact that no other species of Phaseolus, so far as is known, bears this rust. *Dolichos melanophthalmus* DC. which is found to bear *U. vignae* is said by Piper[1] to be a cultivated, blackeyed cowpea of the Mediterranean region synonymous with *V. sinensis*.

The following hosts appear to be correctly placed under *U. appendiculatus: Phaseolus adenanthus* G. Meyer, *P. anisotrichus* Schl., *P. atropurpureus* Moc. & Sesse, *P. coccineus* Jacq., *P. disophyllus* Benth., *P. lunatus* L., *P. obvallatus* Schlecht., *P. polystachyus* (L.) B. S. P., *P. retusus* Benth., *P. vulgaris* L. The status of the rust on *P. lathyroides* L., *P. sinuatus* Nutt., *Strophostyles helvola* (L.) Britton, *S. pauciflora* (Benth.) S. Wats., and *S. umbellata* (Muhl.) Britton is not so clear.

[1] Piper, C. V. Agricultural varieties of cowpea. U. S. Dept. Agric., Bur. Pl. Ind. Bull. 229. 1912.

These have all been referred to *U. appendiculatus* but all show pores slightly above the equator, somewhat intermediate in position between the equatorial pores of this species and the distinctly superequatorial pores of *U. vignae*. They cannot be placed properly with the latter species and they are atypical for *U. appendiculatus*. It is possible that a third species is involved. I have attempted to culture the Strophostyles rust on both beans and cowpeas without success but the circumstances attending the attempts do not warrant a statement that the rust will not pass to either under optimum conditions. Arthur[1] has shown that the Strophostyles rust is autoecious and that it has teliospores of the resting type by producing aecia in the spring with overwintered teliospores.

It seems desirable to supply a more detailed description of the rust of Vigna than that given by Barclay. The pycnia and aecia have not been described and the uredinia and telia have features of taxonomic value not included in Barclay's description. The species is also transferred to the genus Nigredo according to Arthur's treatment of the rusts.

Nigredo vignae (Barcl.) comb. nov.

Uromyces vignae Barcl. Jour. Asiat. Soc. Bengal **60:** 211. 1891.
Uromyces vignae luteolae P. Henn. An. Mus. Congo **2:** 95. 1907.

0. Pycnia epiphyllous, in small circular groups, honey-yellow, becoming brownish, globose or broadly so, 100–125 μ in diameter; ostiolar filaments short.

I. Aecia chiefly hypophyllous and petiolicolous, in circular groups, 2–4 mm. across, often with annular arrangement, low-cupulate, small, 0.2–0.3 mm. in diameter; peridium whitish, rather evanescent, margin spreading, irregularly lacerate; peridial cells rhomboidal or oblong, slightly imbricated, 16–20 × 20–25 μ, the outer wall 3–5 μ transversely striate, smooth, the inner wall 2–3 μ, verrucose; aeciospores ellipsoid or oblong ellipsoid, 16–20 × 20–26 μ; wall colorless, 1–1.5 μ, minutely and closely verrucose.

II. Uredinia amphigenous and petiolicolous, scattered, roundish, rather large, about 1 mm. or less in diameter, soon naked, chestnut-brown, ruptured epidermis evident; urediniospores ellipsoid or ovate-ellipsoid, 18–22 × 24–30 μ; wall cinnamon-brown, moderately thin, 1.5–2 μ, finely and closely echinulate, the pores 2, readily distinguished, markedly superequatorial.

[1] Arthur, J. C. Cultures of Uredineae in 1903. Jour. Myc. **10:** 14. 1904.

III. Telia amphigenous and petiolicolous, roundish, about 0.5 mm. in diameter, early naked, blackish-brown, somewhat pulverulent, ruptured epidermis evident; teliospores broadly ellipsoid, 20–25 × 27–35 μ, rounded or obtuse above, usually rounded below; wall dark chestnut-brown, smooth, moderately thick, 2–2.5 μ, apex 4–6 μ including the hyaline, hemispherical umbo; pedicel hyaline, fragile, rarely equalling the spore length; germinating at maturity.

The collections listed below have been examined by the writer.

On *Dolichos lablab* L., Santiago de las Vegas, Cuba, November 3, 1917, J. R. Johnston; Regla, Prov. Havana, Cuba, April 8, 1903, J. A. Shafer (from phanerogamic specimen); Kanaighat, India, May 24, 1905, E. J. Butler (Sydow Ured. 2101).

On *Phaseolus truxillensis* H.B.K., San Jose, Costa Rica, January 10, 1916, Holway, 397.

On *Vigna repens* (L.) Kuntze, Miami, Florida, March 25, 1903, Holway; Punta Rassa, Lee County, Florida, February 26, 1916, P. C. Standley, 12670; Arecibo, Porto Rico, May 21, 1913, F. L. Stevens, 1760; Mayaguez, Porto Rico, March 3, 1916, Whetzel & Olive, 201; Bahia Honda, Pinar del Rio, Cuba, December 14, 1910, Percy Wilson (from phanerogamic specimen).

On *Vigna sesquipedalis* (L.) W. F. Wight, Honomo, Hawaii, May 1920, L. O. Kunkel.

On *Vigna sinensis* (L.) Endl., Alhambra, California, Fall, 1919, D. C. Milbrath; Ames, Iowa, Fall, 1901, Estella Rhinehart; Lafayette, Indiana, October 17, 1902, J. C. Arthur (N. Am. Ured. 381); Lafayette, Indiana, October 26, 1903, J. C. Arthur; Suling, Texas, August 26, 1909, Heald & Wolf, 2260; Leesville, Texas, August 1, 1902, C. L. Shear; Brownsville, Texas, May 10, 1912, W. P. Carr; Manchester, Missouri, September 26, 1906, H. Von Schrenk; Columbia, Missouri, September 23, 1906, B. M. Duggar; Grady, Alabama, July, 1923, S. A. Wingard; Pensacola, Florida, July 26, 1909, G. W. Carver (N. Am. Ured. 86); Bell, Maryland, August 2, 1921, J. T. Rogers; Arlington Farm, Virginia, September 16, 1907, G. Graham; Blacksburg, Virginia, August 7, 1922, S. A. Wingard; Oahu Sugar Company, Oahu, Hawaii, July 23, 1919, Lyon; Nujingyan, Burma, January 24, 1908, E. J. Butler (Sydow Ured. 2451); Parma, Italy, July, 1874, Passerini (Thüm. Myc. Univ. 40).

On *Vigna vexillata* (L.) A. Rich., Toa, Baracoa, Cuba, April 17, 1916, J. R. Johnston, 586; Campo Florido, Prov. Havana, Cuba, July 18, 1912, Bro. Leon (from phanerogamic specimen); Mayaguez, Porto Rico, June 14, 1913, F. L. Stevens, 2216.

On *Vigna sp.*, Eritrea, Akrur, February 14, 1894, G. Schweinfurth.

The locality of the type collection is near Simla (on Tara Devi), India, on *Vigna vexillata* (L.) A. Rich. (*V. vexillata* Benth).

GEOGRAPHIC DISTRIBUTION

A survey of recent literature gives a number of additional localities and adds materially to the distribution of the rust of cowpea as shown by the herbarium material examined. The rust is, of course, cited as *U. appendiculatus*. An examination of specimens would be necessary before these citations could be placed without question under *U. vignae* but there seems little doubt that the following are referable to this species.

On *Vigna luteola*, Columbia, Central Andes, Mem. Soc. Neuchat. **5**: 462. 1914; Argentine, Hedwigia **35**: 223. 1898.

On *Vigna sesquipedalis*, Philippine Islands, Leaf. Phil. Bot. **6**: 2076. 1914.

On *Vigna sinensis*, Japan, An. Myc. **20**: 82. 1922; Philippine Islands, Phytopathology **9**: 139. 1919; Ceylon, Yearbook Ceylon Soc. Agr. **1919–1920**: 117. 1919; Cuba, Informe Estac. Exp. Agron. Cuba **1918–1919, 1919–1920**: 723–763. 1921; China, An. Phytopath. Soc. Japan **1**: 66. 1921; Russia, Bur. Myc. & Phytopath. Petrograd **1**: 23–41. 1915; India, An. Myc. **10**: 256. 1912.

Apparently the rust of Vigna is cosmopolitan and occurs practically coextensively with the distribution of its hosts in southern Europe, Asia, Japan, the Philippines, the Hawaiian Islands, Africa, South America, Central America, the West Indies, and the United States especially in the southern part. It is recorded from the states of Maryland, Virginia, Alabama, Florida, Indiana, Iowa, Missouri, Texas, and California.

INFECTION STUDIES

The rust material used in the infection studies has been obtained from several sources. The first material came from D. C. Milbrath and was collected at Alhambra, California, in the fall of 1919. It consisted of fresh leaves of Blackeye cowpea bearing viable urediniospores of *U. vignae*. The rust was established in the greenhouse on Blackeye plants and was carried over winter with occasional transfers.

A sowing of 18 varieties of cowpea and 19 varieties of kidney bean was made in the field at Blacksburg, Virginia, in the spring of 1920 and after

suitable growth these were inoculated with urediniospores taken from Blackeye plants in the greenhouse. The inoculation was made on July 10 and uredinia were first noted on the plants of Blackeye on July 22. The infection had developed vigorously on this variety by July 29 and on this date a careful inspection of the other varieties of cowpeas and beans was made. No infection was found on any of the beans and infection of the cowpeas was restricted to four varieties of the Blackeye type recorded as follows:

Vigorous infection: Blackeye.

Slight infection: Large Blackeye, Extra Early Blackeye, Ramshorn Blackeye.

Flecks only: Black, Brabham, Clay, Cream Crowder, Gallavant, Groit, Iron, New Era, Red Ripper, Taylor, Two-Crop Clay.

No flecks nor sori: Crowder, Rice or Cream Pea, Whippoorwill.

The infection at this time consisted of uredinia and telia, the latter occurring especially on the older leaves. It continued to develop vigorously on the Blackeye plants which suffered severe defoliation in consequence. In late August, much to our surprise, an abundant development of aecia was noted on the plants of this variety. Uredinia and telia were found in considerable numbers on Extra Early and Ramshorn Blackeye at this time but there were no aecia and none also on Large Blackeye which showed only slight infection. There were no sporulating sori on any of the other varieties.

An attempt to carry the rust over winter in the greenhouse was a failure owing to the low temperatures maintained which were unsuited to the growth of cowpeas. During the spring of 1921 Blackeye cowpeas with other varieties were sown in the same location in the field as in 1920 in the hopes that infection might result from over-wintered material, but no infection occurred throughout the season. A culture of the rust from Blackeye was again obtained, however, on August 28, 1921, from the farm of the County Experiment Station at Chatham, Virginia. The rusted Blackeye plants were in a variety test which also included the varieties Black, Brabham, Clay, Groit, Iron, Taylor, New Era and Whippoorwill, none of which showed infection. Although the rust was in the telial stage only an attempt to establish a culture was made on Blackeye plants in the greenhouse on September 10. Pycnia followed by aecia appeared on the inoculated plants on September 19. A second sowing of the material from Chatham was made on other Blackeye plants on September 19 and pycnia were obtained on September 28.

Aeciospores from the culture of September 19 were used as inoculum

in the greenhouse on October 18 on plants of Blackeye and Black cowpea, on adsuki bean (*Phaseolus angularis* (Willd.) W. F. Wight), asparagus bean (*Vigna sesquipedalis*), hyacinth bean (*Dolichos lablab*), mung bean (*P. aureus* Roxb.), bubb catjang (*V. catjang* (Burm.) Walp.), rice bean (*P. calcaratus* Roxb.), sword bean (*Canavalia gladiata*), scarlet runner (*P. multiflorus* Willd.), and urd bean (*P. mungo* L.). Infection (uredinia) was obtained only on Blackeye. A repetition of the foregoing test was made November 1, using urediniospores from Blackeye on the same series of plants. Vigorous infection was obtained on Blackeye and none resulted on any of the other plants. A third attempt made on the same series of plants growing in a garden at Blacksburg in the summer of 1922 gave the same results. No plants except those of Blackeye showed infection. Several additional attempts were made to secure infection with the cowpea rust on a number of varieties of kidney bean and lima bean, but all were without success.

From the foregoing it is apparent that the rust of cowpea is closely limited in its host range. Of the varieties of cultivated cowpeas tested it has infected only Blackeye and closely related strains and has produced no infection on the kidney, lima or other types of bean included in the tests.

Piper's observations (l. c.) on the development of rust in cowpeas under comparative tests at Arlington, Virginia, furnish additional data as to varietal susceptibility. He writes:

> Rust is a disease to which most standard American varieties of cowpeas are immune. Many recently imported varieties, especially from China and India, are, however, very susceptible to this disease and suffer severe injury from it. That other varieties are completely immune to rust would appear from the fact that they are never affected even when growing contiguous to a rusted variety on the same ground for several years in succession, which has been the experience at Arlington Farm. This disease was very much in evidence at Arlington in 1908 and 1909, but was entirely absent in 1910.

Piper's tests included a large number of named varieties and in addition a number of importations from foreign countries many of which are listed by number only. Notes as to behavior with respect to rust infection are included in the descriptions and discussions of the varieties and introductions. The named varieties of cowpea on which the presence of rust is recorded are: Browneye, Chinese Black, Chinese Red and Chinese Whippoorwill. It also occurred on a number of the unnamed introductions of cowpea, catjang and asparagus bean. The following varieties of cowpea are recorded as free from rust: Ayrshire, Black, Black

Crowder, Blackeyed Lady, Brabham, Brown Coffee, Brown Crowder, Browneye Crowder, Cotton Patch, Cream, Delaware Red, Early Black or Congo, Early Blackeye, Early Red, Grayeye, Groit, Guernsey, Holstein, Iron, Lady, Louisiana Wild, Michigan Favorite, New Era, Old Man, Panmure Early Wonder, Peerless, Powell Early Prolific, Purple-Podded Clay, Ramshorn Blackeye, Red Crowder, Red Ripper, Red Whippoorwill, Red Yellowhull, Self-Seeding Clay, Sixty-Day, Small Black Crowder, Smallpox, Southdown, Speckled Crowder, Taylor, Unknown, Unknown Blackeye, Warren New Hybrid, Watson, Whippoorwill, Whippoorwill Crowder, White Giant, Wight Black Crowder.

It is to be noted that none of the varieties recorded as susceptible to rust by Piper were included in our tests and that the observations with respect to those varieties which were included in both tests are in agreement except that the writer obtained moderate infection on Early Blackeye and Ramshorn Blackeye while Piper records these varieties as free from rust. Certain introductions of asparagus bean were found to be susceptible by Piper while others were rust free. My attempts to infect asparagus bean were made with a single variety, Yard Long, and it seems probable that successful infection might have been obtained if more varieties or strains had been available. It is possible, of course, that there are two or more biologic strains of the cowpea rust. According to L. O. Kunkel the rust of asparagus beans is common in the Hawaiian Islands. In a latter dated March 14, 1920, he writes:

> I have not found rust on beans out here (Honolulu) and there is no record of its occurrence here at the station. However, what is supposed to be the same thing is common enough on the Yard Long bean, *Vigna sp.* I have collected rust on this host on this island and also on the island of Hawaii. Phaseolus plants are always free from rust.

Although I have made no extended test of teliospore germination with either the cowpea or bean rust it is evident from their behavior in culture that *U. vignae* has teliospores of the non-resting type, while those of *U. appendiculatus* require a considerable period of after-ripening prior to germination. Aecia of *U. vignae* have been produced in the field in August from teliospores produced during the same season, and also in the greenhouse on several occasions during fall, winter and spring from teliospore inoculation. This occurred in two separate trials in September, 1921, with teliospores taken from the field and again in November, 1922. Teliospores taken from the field November 24, 1922, showed germination on this date but none were viable in later tests. A culture carried through the winter of 1919 in the greenhouse produced aecia in the spring from teliospore inoculation. The rust had gone through

several uredinial generations in the greenhouse and the teliospores used as inoculum had been produced but a short time previously.

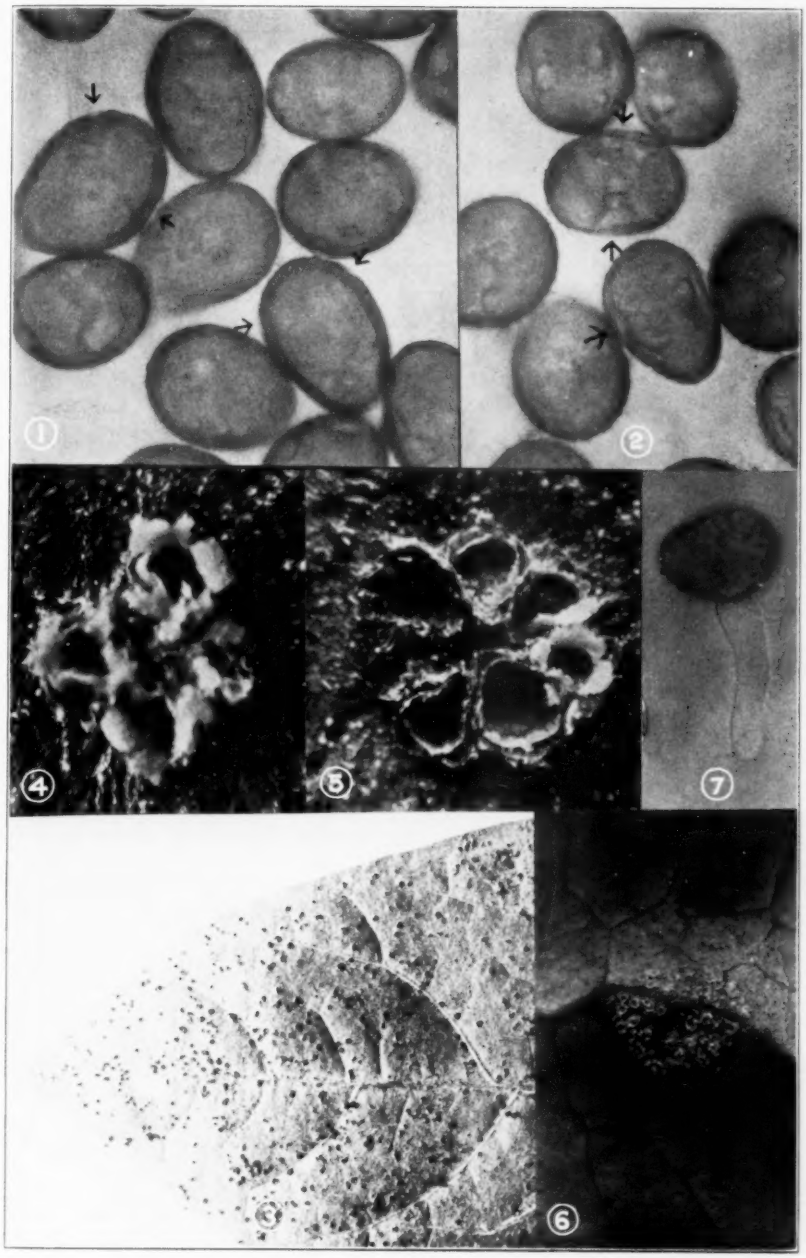
In contrast with this behavior of the cowpea rust the bean rust during seven years of experimental study in both greenhouse and field has never produced aecia. The writer has watched for the initial appearance of bean rust in gardens in spring and early summer and invariably uredinia only have been observed, followed later in the season by telia. Teliospores at the time of maturity have been used as inoculum without results. No systematic attempt at the overwintering of teliospores has been made and evidence in regard to their germination is lacking. Such evidence as may be gained from a study of herbarium material indicates that aecia of bean rust are rare in the United States and it seems probable that the teliospores do not function as a rule in the overwintering of the fungus. Specimens of bean rust in the Arthur herbarium and in that of the U. S. Department of Agriculture have been examined, and although a great many collections from North America are present only one shows aecia; this is on *P. vulgaris* from LaCrosse, Wisconsin, July 25, 1908. A collection by Underwood on *Phaseolus sp.* from Jamaica, September 2–10, 1906, also shows aecia but the identity of the host is somewhat doubtful. Several European collections which show aecia have been seen by the writer but they are said by Fisher (l. c.) to occur but rarely in Europe. I know of but one additional collection from North America on Phaseolus which shows aecia. This material which is of a pole bean (*P. vulgaris*) was sent me from a garden at Blacksburg, Virginia, on July 8, 1916. I did not know at the time that aecial production in the bean rust was unusual and did not visit the garden to study the case.

So far as I am aware no one has carried the bean rust through its complete cycle or developed aecia from teliospore infection except possibly deBary[1] who, however, gives no details of his work with this species. He states that he obtained the same results with the rust of beans as with *Uromyces fabae* for which he describes cultures establishing the relation between the three spore forms. There seems no question as to the autoecism of the bean rust but the fact has not been established on as definite a basis as is desirable.

SUMMARY

The rust of cowpeas which has commonly been considered identical with the rust of beans, *Uromyces appendiculatus*, is presented as a clearly

[1] deBary, A. Recherches sur le development de quelques champignons parasites. An. Sci. Nat. Bot. IV. **20**. 1863.



RUST OF COWPEA

UNIV. OF MICH.

defined species and is assigned to *Uromyces vignae* as described by Barclay from *Vigna vexillata*. A new description of the species is given. Marked distinguishing features between the two species are found in the grouping of the aecia, the location of urediniospore germpores, and in the germination of the teliospores. The teliospore of *U. vignae* is of the non-resting type while that of *U. appendiculatus* is of the resting type.

Occurrence of *U. vignae*, from a study of herbarium material, is recorded on four species of Vigna, one of Dolichos and one of Phaseolus.

Infection studies with a strain of the rust obtained from the Blackeye variety of cowpea show it to be closely restricted in its host range. It has infected only a few varieties or strains of the Blackeye type. The great majority of cowpea varieties grown in the United States are immune or highly resistant. No infection has been obtained on hyacinth bean or asparagus bean which are hosts according to the taxonomic treatment. This failure may be due to lack of the proper variety or strain of these hosts for testing or it may be that there is more than one biologic strain of the rust.

Uromyces vignae has produced aecia under field conditions in August and during fall, winter and spring in the greenhouse from newly matured teliospores. It is the only full-cycled, autoecious rust known to the writer which completes its full cycle under greenhouse conditions.

EXPLANATION OF PLATE I

FIG. 1. Urediniospores of *Uromyces vignae* from Blackeye cowpea. The pores are designated by arrows and are superequatorial. Approximately 900 ×.

FIG. 2. Urediniospores of *U. appendiculatus* from Tennessee Green Pod bean. The pores, designated by arrows, are equatorial. Approximately 900 ×.

FIG. 3. Uredinia of *U. vignae* on a leaf of Blackeye cowpea. About 1½ ×.

FIG. 4. Aecia of *U. appendiculatus* from *Phaseolus vulgaris* showing "kreuz formige" grouping. The group contains 4 aecia. About 30 ×.

FIG. 5. Aecia of *U. appendiculatus* from *P. vulgaris* showing rosette grouping. The group contains 7 aecia. About 30 ×.

FIG. 6. Aecia of *U. vignae* on a leaf of Blackeye cowpea showing annulate grouping. About 5 ×.

FIG. 7. Urediniospore of *U. appendiculatus* showing the germ-tube issuing from an equatorial pore. Approximately 600 ×.

CURLY LEAF TRANSMISSION EXPERIMENTS

HENRY H. P. SEVERIN

WITH ONE FIGURE IN THE TEXT

DIRECT INOCULATION WITH JUICE FROM CURLY LEAF BEETS IN WHICH THE DISEASE HAD BEEN PRODUCED BY THE BEET LEAFHOPPER (EUTETTIX TENELLA BAKER)

Smith and Boncquet (4) failed to produce curly leaf by artificial inoculation with the juice of diseased beets, the liquid being atomized "upon uninjured surfaces, through large and small wounds in the leaves, petioles and roots, and by inserting the material into various parts of the plant in capillary glass tubes which were broken off and allowed to remain in the tissue." These inoculations were made at various degrees of temperature and humidity, but all without effect.

During the past five years mostly failures have been recorded in our endeavor to cause curly leaf by inoculating the petioles of healthy beets at some distance from the crown with juice from blighted beets in which the disease had been produced by the beet leafhopper (*Eutettix tenella* Baker). The exudation from the leaves of curly leaf beets in the field, such as the clear viscid liquid which later becomes black and sticky and upon drying forms a brown crust, when inoculated in all stages into the petioles of healthy beets failed to produce curly leaf.

In 1921 occurred the first typical case of curly leaf caused by inoculation. Juice was pressed from the two inner leaves of a beet showing an early stage of the disease,—namely, the transparent network of minute veins. The cleared veinlets were evident on September 9, and the juice was pressed from the beet on September 14, or five days later. A cooled flamed needle was forced about an inch into the crown of a healthy beet between the bases of the petioles and droplets of juice were placed in this wound by means of a sterilized pipette. The inoculated beet showed the first visible symptom of curly leaf on October 20, or 36 days after inoculation. Six other beets inoculated with the juice from three diseased beets failed to develop the disease.

Mr. C. C. Epling in his thesis work carried on under the direction of the writer, conducted daily inoculations with the juice from sugar beets upon which infective beet leafhoppers had fed from 1 to 8 days or until the first visible symptom of curly leaf appeared. A single case of curly leaf was produced in one of the inoculated beets in which the juice was pressed from the youngest or innermost leaf of an infected beet into an

incision in the petiole of a healthy beet. Thirty infective beet leafhoppers had fed on the infected beet for a period of five days and the cleared veinlets of curly leaf appeared at the end of eleven days. The first visible symptom of the disease in the inoculated beet developed at the end of seven days.

During 1923, nine typical cases of curly leaf were produced in beets about an inch in diameter by inoculating with juice from beet seedlings in an advanced stage of the disease,—namely, that characterized by nipple-like papillae and knot-like swellings on the distorted veins. The juice was first extracted from the leaves showing curly leaf symptoms and later from the beet root by means of a porcelain press. The juice was sucked up into dropping pipettes, these having a bulb in the center which prevented the liquid from entering the rubber bulb. A flamed needle after cooling was forced from 1 to 1½ inches into the crown of the healthy beet between the bases of the petioles. Several punctures were made in each beet but too many wounds will cause the outer leaves to die. A drop of beet juice was put over each hole and the needle was forced up and down in the wound. When the drop of beet juice disappeared another drop was put over the hole in the crown. During May, June and July, 62 healthy beets were inoculated with juice pressed from the leaves of curly leaf beets and 28 healthy beets were inoculated with the juice extracted from the roots of diseased beet seedlings. During the three months, healthy beets used as checks or controls were punctured in the crown with a cooled flamed needle. Three other lots of healthy beets were inoculated with juice pressed from healthy beet seedlings. All checks or control beets remained healthy.

The period from the date of inoculation until the earliest visible symptom of curly leaf appeared was as follows: 12, 12, 24, 25, 29 and 39 days respectively in six beets inoculated with the juice pressed from diseased beet leaves; 18, 20 and 24 days respectively in three beets inoculated with the juice extracted from the roots of curly leaf beets.

Non-infective beet leafhoppers, allowed to feed on the inoculated beets after curly leaf developed, transmitted the disease to healthy beet seedlings. Thirty-one lots of 20 non-infective beet leafhoppers enclosed in cages were allowed to feed on the nine inoculated diseased beets for a period varying from 2 to 7 days. Then each batch of 20 insects was transferred to a healthy beet seedling. The 31 beet seedlings developed the first visible symptom of curly leaf in from 2 to 13 days. On the other hand, non-infective beet leafhoppers, when allowed to feed on inoculated beets which did not develop curly leaf symptoms, failed to transmit the disease to healthy beet seedlings.

CAUSATIVE AGENT OF CURLY LEAF DISTRIBUTED IN ENTIRE BEET

Foliage.—The infective principle of curly leaf is generally distributed in the foliage and beet root. The evidence for this was obtained by feeding non-infective beet leafhoppers on various parts of the diseased beet and then transferring them to healthy beets. After a beet developed faint indications of transparent venation on a portion of the youngest leaf, non-infective adults were fed on the three outer leaves showing no visible sign of the disease. On each of the three days following 25 adults were transferred from the outer leaves of the infected beet to a healthy beet. The three beets used developed curly leaf. This experiment was repeated three times. In one case the first two beets remained healthy but the third showed the symptoms of the disease.

Hairy rootlets.—The causative agent of curly leaf was transmitted to healthy beets by non-infective beet leafhoppers which had fed on the hairy rootlets of diseased sugar beets. Badly blighted sugar beets obtained from the San Joaquin Valley were planted and after a new growth of hairy rootlets developed, these rootlets were removed and dropped on moist filter paper in a glass jar or caused to adhere to the sides of the jar. Thirty non-infective adults were confined in the jar, a fresh supply of the rootlets being added each day. Ten adults were removed daily and transferred to a healthy beet. The three healthy beets on which these insects had fed developed the disease.

Roots.—In similar experiments it was found that the disease-producing factor of curly leaf was transmitted to healthy beets by non-infective beet leafhoppers which had fed on the main roots and tap root of a diseased beet with the hairy rootlets removed.

Beet root.—The disease was also communicated to healthy beets when the non-infective hoppers had fed on the beet root with the main roots and hairy rootlets removed.

CURLY LEAF NOT TRANSMITTED FROM BEET TO BEET

The question has been asked frequently whether the soil is contaminated with curly leaf by the plowing under of badly blighted sugar beets. Fields of diseased beets are often plowed under during the spring and summer and beets planted on the same soil during the winter or following spring.

An experiment was conducted in the San Joaquin Valley to determine whether healthy beets could become infected with curly leaf as a result of the root system coming in contact with blighted sugar beets. A layer of badly diseased sugar beets were buried in the soil at the same depth at

which the land was plowed. The beets were inverted so that the tops rested 12 inches below the surface of the soil and the beet roots projected upward, thus preventing growth. The surface of the soil covering the buried beets was enclosed with a cage. Beet seeds were planted on March 8. On October 9, all beets were in a healthy condition in the cage.

Healthy beets failed to develop curly leaf at the end of six months when transplanted in flower pots so that the root system came in contact with the following parts of blighted beets: chopped leaves showing transparent venation only and others with the protuberances on the lower surface of the leaves; clusters of blighted bud leaves; chopped and sliced beet roots; and a combination of chopped leaves and beet roots. Two series of experiments were performed by planting European and American grown seeds, the latter obtained from blighted stechlings and mother beets. Not a single case of curly leaf developed.

In the last experiment the long tap roots of 16 healthy beet seedlings were twisted around the tap roots of 16 blighted beets. The former remained healthy during the period of three months that the experiment was continued. This experiment was first performed by Professor R. E. Smith with similar results.

RATE OF MOVEMENT OF CAUSATIVE AGENT OF CURLY LEAF IN PETIOLE

An experiment was conducted to determine the shortest time required for the infective principle of curly leaf to travel the length of a beet leaf petiole to the beet root. A potted sugar beet was placed in a cage with the blade of an outer leaf projecting into a second cage. In the second cage were 50 infective males which had undergone a fast of 3½ hours. These could feed on the blade of the outer leaf but not on its petiole. In the narrow space between the two cages, the petiole was covered with cotton. At the end of the desired time, the petiole was cut off at the crown of the beet. The shortest time for the movement of the infective agent was one-half hour at a mean temperature of 103.5° F. through a petiole seven inches long. In a similar experiment, except that 25 infective males were used the pathogenic factor travelled 3¼ inches in one-half hour at a mean temperature of 102° F. Ten beets failed to develop curly leaf symptoms.

In another experiment using 25 infective males, the movement of the causative agent of curly leaf in the petiole at the end of one hour was as follows:

Petioles 4¾ and 5½ inches long. Mean temperature 100.5° F.

Petioles of two beets 3½ inches long. Mean temperature 94° F. Five beets failed to develop the disease.

Forty-two trials reducing the time to 15, 10 and 5 minutes gave negative results. The number of infective leafhoppers was increased, using from 100 to 500 insects. To insure feeding of as many as possible of the hoppers in such a short exposure of the leaf, the cages were covered with black sateen except on one side through which the light entered the cage. The blade projected in the cage toward the side through which the light entered, and large numbers of adults were induced to congregate on the blade.

CURLY LEAF TRANSMISSION FROM INFECTIVE TO NON-INFECTIVE BEET LEAFHOPPERS ON VARIOUS LEAVES OF SUGAR BEET

In the first series of experiments an attempt was made to determine how soon the causative agent of curly leaf was transmitted from infective beet leafhoppers feeding on the outer or oldest leaves to non-infective hoppers on the inner or youngest leaves of a sugar beet. The outer leaves of a beet were projected into two cages, each containing 75 infective adults, while the inner leaves were enclosed in a third cage containing 150 non-infective males. The petioles of the outer leaves were enclosed in paraffine paper and were covered with sand and cotton at the crown of the beet. Twenty adults were removed daily for seven days from the cage enclosing the youngest leaves and were transferred to seven successive healthy beets. The disease was transmitted from infective adults feeding on the outer leaves to non-infective specimens on the inner leaves at the end of six days at a mean temperature of 87.7° F. The seventh beet also developed curly leaf symptoms. The original beet exposed to the influence of both infective and non-infective adults showed the transparent venation of curly leaf at the end of nine days.

In a similar experiment the disease was transmitted from infective adults feeding on the outer leaves to non-infective hoppers on the inner leaf at the end of 10 days at a mean temperature of 80.1° F. The original beet showed the first visible symptom of curly leaf at the end of nine days.

Negative results were obtained at the end of 8, 10 and 10 days when the feeding of the leafhoppers was reversed; i. e., when the infective adults were fed on the youngest leaves and the non-infective insects on the oldest leaves. The original beets had from 10 to 14 leaves.

A different method was used in determining curly leaf transmission from infective to non-infective beet leafhoppers on the outer and inner leaves of small beets, owing to the fact that the feeding of a large number

of hoppers killed the seedlings. A small leaf-cage containing six infective males was fastened to one of the first two outer leaves (Fig. 1) and another leaf-cage enclosing six non-infective males was attached to one of the inner or youngest leaves (Fig. 1) of a potted seedling having usually four true leaves. The beet was enclosed in a cage. This experiment was repeated 84 times. At the end of 1 to 4 days, the leaf-cage confining the six infected adults was removed, the specimens taking no

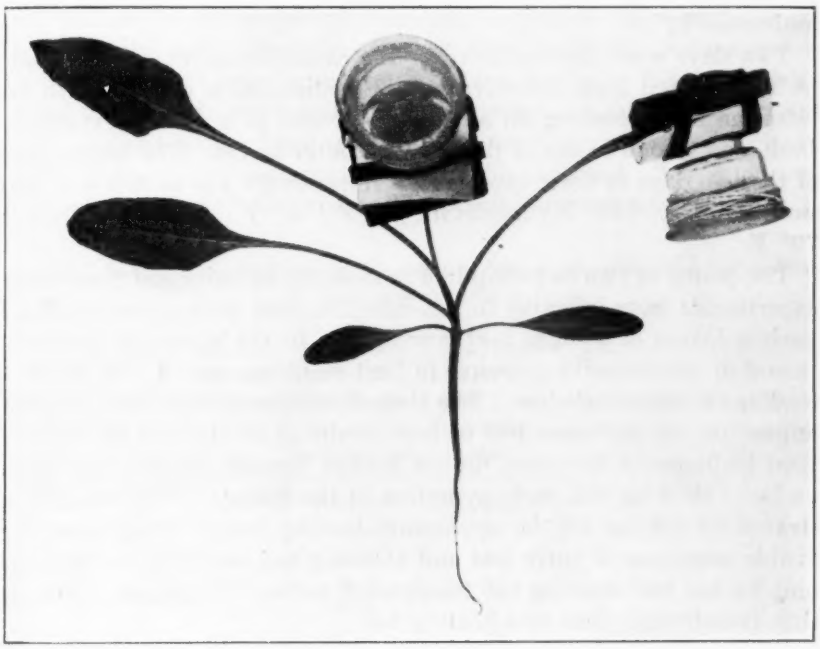


FIG. 1. Small leaf cages used for aphid experiments.

further part in the experiment. The leaf-cage containing the six non-infective males was removed at the end of 1 to 4 days and liberated in a cage enclosing a healthy beet. The disease was transmitted from infective males on the outer leaf to non-infective males on the inner leaf at the end of four days in 5 of 12 beets to which the males had been transferred. The temperature of the four days was as follows: maximum 107° F.; minimum 56° F.; and mean 79.8° F. Negative results were obtained at the end of 1 to 3 days with 72 beets.

Infective beet leafhoppers were allowed to feed on the inner or youngest leaf of the beet seedling while at the same time non-infective males

fed on one of the first two outer leaves. The non-infective males became infective at the end of two days, as was proved by transferring them to a healthy beet. The temperature of the two days was as follows; maximum 104° F.; minimum 50° F.; and mean 81.2° F.

The infective principle of curly leaf was transmitted from infective beet leafhoppers feeding on one of the first two outer leaves to non-infective males feeding on the opposite outer leaf at the end of two days at the following temperatures: maximum 108° F.; minimum 55° F.; and mean 81° F.

Two days were also required for the causative agent of curly leaf to be transmitted from infective adults feeding on a cotyledon to non-infective males feeding on an inner leaf and in a second experiment, from a cotyledon to one of the first two outer leaves. The temperatures of the two days in these experiments respectively was as follows: maximum 107° F., 102° F.; minimum 65° F., 60° F.; and mean 83.3° F., 79° F.

The period of two days required in most of the curly leaf transmission experiments from infective to non-infective beet leafhoppers feeding on various leaves of a sugar beet corresponds to the minimum incubation period of the infective principle in beet seedlings with 4 to 6 leaves including the two cotyledons. The cleared veinlets of curly leaf sometimes appear on the youngest leaf of beet seedlings at the end of two days. Beet leafhoppers, however, do not always become infective by feeding on beets showing this early symptom of the disease. This was demonstrated by cutting off the apparently healthy leaves which showed no visible symptom of curly leaf and allowing non-infective males to feed only on the leaf showing the transparent network of minute veins, and then transferring them to a healthy beet.

BEET LEAFHOPPER INFECTIVE DURING ALL NYMPHAL STAGES

The beet leafhopper is capable of transmitting curly leaf during all nymphal stages. Twelve nymphs after hatching were fed upon a curly leaf beet during one day and then transferred to a healthy beet, which showed curly leaf symptoms nine days later. After each molt a different lot of 12 nymphs were fed for one day on blighted beets and they then transmitted the disease to healthy beets. During the process of the last molt, three non-infective adults were transferred to curly leaf beets for one day and the next day were confined in three cages, each enclosing a healthy beet. The three beets developed curly leaf.

According to Shaw (2) nymphs produce the symptoms of curly leaf

much more rapidly than do the adult insects, hence the nymphs are more virulent. There is such a wide variability as to the duration of the developmental period of curly leaf symptoms in beets of the same age, under the same conditions of temperature, humidity and sunshine, and infected by the same number of nymphs and adults, that we are hardly justified in stating that nymphs are more virulent than adults on the rate of curly leaf development.

An attempt was made to put to an experimental test Shaw's view that nymphs are more virulent than adults. A nymph upon hatching and a non-infective male after the last molt were confined in a cage enclosing a curly leaf beet upon which both fed for one day. The next day the nymph and male were put in separate cages. Each nymph and male was supplied with a healthy beet daily until the nymphs acquired the winged stage when the experiment was discontinued. The same experiment was repeated six times. The results are indicated in table 1.

TABLE 1—*Comparison of number of curly leaf beets produced by nymphal instars and males infective after last molt.*

Number of beets fed upon 1 day by each nymph	Number of curly leaf beets caused by each nymph	Percentage of curly leaf beets caused by each nymph	Number of beets fed upon 1 day by each male	Number of curly leaf beets caused by each male	Percentage of curly leaf beets caused by each male
33	4	12.1	33	0	0.0
34	2	5.8	34	10	29.4
34	6	17.6	34	1	2.7
37	6	16.2	37	6	16.2
37	7	18.6	37	9	24.3
38	9	23.6	38	13	34.2
213	34	15.9	213	39	18.3

There is no evidence from table 1 to show that nymphs are more virulent than adults. It is evident that the nymphs do not lose their infectivity during the process of molting.

BEET LEAFHOPPER INFECTIVE DURING ENTIRE ADULT LIFE

Boncquet and Stahl (1) assert that the ability of the beet leafhopper to transmit curly leaf was lost in from 15 to 35 days if the insects were transferred daily to healthy beets.

An experiment somewhat similar to the one which Bonequet and Stahl (1) had performed was conducted. Eight infective first brood males which had completed all of the nymphal stages on a blighted beet, acquired the winged stage on April 19, and were confined singly in eight cages on this date. A healthy beet seedling with from 4 to 6 leaves was placed in each cage daily until the males died. Males were used instead of females to avoid egg deposition, since the beets were kept in insect-proof compartments until the symptoms of curly leaf developed. The following data concerning the largest and smallest number of blighted beets produced by two males are given rather than of the entire eight specimens. The maximum and minimum temperatures follow after each date on which the male transmitted curly leaf.

April 19/ 22, 109°, 50° F.; 20, 104°, 55° F.; 22, 100°, 56° F.; 25, 72°, 53° F.; 26, 107°, 52° F.; 27, 104°, 50° F.; 28, 106°, 50° F.; 29, 102°, 54° F.; May 2, 114°, 55° F.; 4, 102°, 58° F.; 6, 100°, 50° F.; 8, 100°, 45° F.; 9, 93°, 45° F.; 12, 104°, 52° F.; 13, 106°, 56° F.; 17, 82°, 55° F.; 18, 74°, 56° F.; 19, 74°, 54° F.; 20, 98°, 49° F.; 24, 112°, 50° F.; 25, 106°, 53° F.; 27, 110°, 59° F.; 28, 104°, 58° F.; 29, 104°, 58° F.; 30, 110°, 58° F.; June 2, 111°, 54° F.; 4, 112°, 60° F.; 5, 108°, 60° F.; 6, 104°, 64° F.; 7, 100°, 62° F.; 11, 92°, 59° F.; 15, 103°, 56° F.; 16, 104°, 57° F.; 18, 119°, 61° F.; 21, 120°, 57° F.; 23, 106°, 60° F.; 24, 110°, 60° F.; 28, 93°, 62° F.; July 4, 95°, 64° F.; 6, 88°, 62° F.; 13, 104°, 62° F.; 14, 104°, 58° F.; 15, 104°, 60° F.; 16, 92°, 62° F.; 27, 114°, 60° F.; 28, 96°, 58° F.; 29, 96°, 60° F.; 31, 112°, 60° F.; August 1, 87°, 58° F. Died August 3. Total 107 beets, 49 curly leaf beets or 45.7 per cent.

April 19/22, 109°, 50° F.; 20, 104°, 55° F.; 22, 100°, 56° F.; 28, 106°, 50° F.; May 2, 114°, 55° F.; 4, 102°, 58° F.; 22, 116°, 52° F.; 23, 103°, 51° F.; 28, 104°, 58° F.; June 20, 104°, 59° F.; 22, 110°, 58° F.; July 13, 104°, 62° F.; 14, 104°, 58° F.; 25, 110°, 56° F. Died August 1. Total 105 beets, 14 curly leaf beets or 13.3 per cent.

It is evident from the above figures that the males transmitted curly leaf at irregular intervals and under a wide range of temperature.

There is a marked variability as to the number of times a male, during its adult life, can transmit curly leaf when provided with a healthy beet daily as indicated in table 2. Temperature, humidity and sunshine were identical for the eight males used in this experiment.

The males usually transmitted curly leaf to fewer beets toward the end of their natural life. The interval between the last beet infected with the disease by each hopper and the death of the insect was in most cases less than the longest period elapsing between the infection of two successive beets as is shown in table 2.

TABLE 2—*Data on infectivity of beet leafhopper during adult life.*

Number of beets fed upon 1 day by each male	Number of curly leaf beets caused by each male	Percentage of curly leaf beets caused by each male	Longest period between two curly leaf infections (days)	Period between last curly leaf infection and death of male (days)
116	25	21.5	13	15
108	24	22.2	15	5
107	49	45.7	13	2
105	14	13.3	21	7
86	14	16.2	19	19
82	36	43.9	6	7
64	15	23.4	15	10
27	15	55.5	14	5
695	192	27.6	14.5	8.7

A comparative study was made of the number of curly leaf beets caused by each infective beet leafhopper which was provided with a healthy beet daily with the following experiments: (1) each infective male was allowed to feed alternating daily on a healthy and a diseased beet; (2) each infective male was supplied with a healthy beet at the end of every second day. Second brood males were employed which had fed during

TABLE 3—*Comparison of number of curly leaf beets caused by infective male beet leafhopper feeding on successive beets daily, for two days and alternating daily on healthy and curly leaf beets.*

Four infective males each provided with healthy beets daily			Four infective males each allowed to feed two days on each healthy beet			Three infective males each allowed to feed alternating daily on healthy and diseased beets		
Healthy beets	Curly leaf beets		Healthy beets	Curly leaf beets		Healthy beets	Curly leaf beets	
No.	No.	%	No.	No.	%	No.	No.	%
86	28	32.5	64	14	21.8	21	7	33.3
66	23	34.8	40	14	35.0	18	7	38.8
55	24	43.6	30	16	53.3	15	5	33.3
52	18	34.6	21	4	19.0			
259	93	35.9	155	48	30.9	54	19	35.1

all of the nymphal stages on blighted beets and passed through the last molt on June 1 to 2. Beet seedlings with 4 to 6 leaves were used. The results are indicated in table 3.

A glance at table 3 shows no marked differences in the average percentages in the first and third experiments.

In the next experiment 1, 2, 3, 4 and 5 infective males which had completed all of the nymphal stages on a blighted beet were confined in five cages in the greenhouse. A healthy beet was placed in each cage daily. When a leafhopper died, another was put into the cage, except the one containing a single specimen. The experiment extended over a period of 54 days from November 1 to December 24, 1920, and was discontinued when the single male died. The results follow:

One infective male transmitted curly leaf to 3 beets or 5.5 per cent in 54 days.

Two infective males transmitted curly leaf to 10 beets or 18.5 per cent in 54 days.

Three infective males transmitted curly leaf to 31 beets or 57.4 per cent in 54 days.

Four infective males transmitted curly leaf to 28 beets or 51.8 per cent in 54 days.

Five infective males transmitted curly leaf to 28 beets or 51.8 per cent in 54 days.

Mean maximum 78.9° F., mean minimum 61.7° F., mean 70.3° F., temperatures.

Two similar experiments were performed except that when a leafhopper died, another male was *not* put in the cage as in the preceding experiment. The first of these two experiments extended over a period of 134 days from April 1 to August 12; the second over a period of 114 days from April 15 to August 7, and both were discontinued when the last male died. The results are indicated in table 4.

An examination of Table 4 shows that a higher average percentage of curly leaf was transmitted by the males in the first experiment (33.5 per cent) than in the second experiment (21.6 per cent). When the number of leafhoppers was reduced to one, there were periods of 8, 20, 47 and 56 days in which no curly leaf was produced.

CONTAMINATION OF MOUTH-PARTS WITH BACILLUS MORULANS

Smith and Boncquet (3), Townsend (5) and Brown have found lesions or pockets containing bacteria in sugar beets affected with curly leaf but inoculations with pure cultures of these bacteria failed to produce

TABLE 4—*Number and percentages of curly leaf beets caused by 1 to 5 infective male beet leafhoppers provided with a healthy beet daily in two experiments.*

Dates 1921	No. of ♂♂	No. of beets	No. of curly leaf beets	Percentage of curly leaf beets	Dates 1921	No. of ♂♂	No. of beets	No. of curly leaf beets	Percentage of curly leaf beets
4/1-6/12	1	73	16	21.9	4/15-7/1	1	78	5	6.4
4/1-17	2	17	9	52.9	4/15-29	2	15	9	60.0
4/18-22	1	5	2	4.0	4/30-6/28	1	60	4	6.6
		22	11	50.0			75	13	17.3
4/1-4	3	4	3	75.0	4/15-5/16	3	32	12	37.5
4/5-5/2	2	28	11	39.2	5/17-6/21	2	36	5	13.8
5/3-6/5	1	34	3	8.8	6/22-8/7	1	47	0	00.0
		66	17	25.7			115	17	14.7
4/1-5/31	4	61	42	68.8	4/15-5/20	4	36	20	55.5
6/1-15	3	15	4	26.6					
6/16-6/17	2	2	0	00.0	5/21-31	2	11	2	18.1
6/18-8/12	1	56	0	00.0	6/1-7/8	1	38	4	10.5
		134	46	34.3			85	26	30.5
4/1-7	5	7	7	100.0	4/15-22	5	8	8	100.0
4/8-17	4	10	8	80.0	4/23-5/25	4	33	17	51.5
4/18-5/26	3	39	17	43.5	5/26-31	3	6	2	3.3
5/27-6/14	2	19	5	2.6	6/1-24	2	24	8	3.3
6/15-22	1	8	0	0.0	6/25-7/14	1	20	0	0.0
		83	37	44.5			91	35	38.4

the disease. To determine whether the beet leafhopper increases the virulence of *Bacillus morulans* as suggested by Smith and Boncquet (3) the mouth-parts were contaminated with this bacterium. The bacteria were rubbed on the mouth-parts of torpid non-infective hoppers with sterilized camel's hair brushes. The adults were put into a torpid condition by chilling them in a phial embedded in chipped ice. The insects had been previously fasted for a period of 6 to 8 hours with the hope that they would feed and inject the bacteria with the saliva into the beet foliage shortly after overcoming their numbness. This experiment was repeated with 141 adults, but not a single case of curly leaf developed.

Non-infective beet leafhoppers were allowed to feed on beet seedlings with a portion of a leaf covered with *B. morulans*,[1] so that in making the

[1] Miss E. H. Smith prepared the cultures of *B. morulans* which were determined by Professor R. E. Smith, Department of Plant Pathology, University of California.

feeding puncture it was presumed that the mouth-parts would become contaminated and some of the bacteria would be injected into the leaf. The hoppers, which had been fasted from 6 to 8 hours, were confined in small leaf-cages (Fig. 1) enclosing the bacteria. This experiment was conducted with 190 nymphs and 22 adults, using 61 beet seedlings but no curly leaf developed.

SUMMARY

Juice pressed from the leaves and roots of curly leaf beets when inoculated into the crown of healthy beets caused typical curly leaf symptom in nine of one hundred beets. The period from the date of inoculation until the earliest visible symptom of curly leaf developed varied from 12 to 39 days. Non-infective beet leafhoppers, when allowed to feed on the inoculated beets after curly leaf developed, transmitted the disease to healthy beets, the earliest symptom appeared in from 2 to 13 days.

The causative agent of curly leaf is generally distributed in the foliage and beet root.

Field and laboratory experiments demonstrate, beyond any question of doubt, that curly leaf is not transmitted through the soil or from beet to beet.

The shortest time required for the infective principle of curly leaf to travel through a beet petiole seven inches long was one-half hour at a mean temperature of 103.5° F.

Four[1] days were required for the pathogenic factor to be transmitted from infective adults feeding on one of the first two outer leaves to non-infective males feeding on the inner or youngest leaf of a beet seedling, as was proved by transferring the latter to a healthy beet. Two days were required for the inciting agent of curly leaf to be transmitted from infective leafhoppers feeding on the inner leaf to non-infective males on the outer leaf of a beet seedling, also from one of the first two outer leaves to the opposite outer leaf and from one cotyledon to the inner leaf and from one cotyledon to one of the first pair of outer leaves.

Infective beet leafhoppers retained their infectivity during all of the nymphal stages, after each molt, and during the entire adult life.

Non-infective beet leafhoppers which had been fasted and then the mouth-parts contaminated with *Bacillus morulans* isolated from curly

[1] Since sending this manuscript to the editor, the period of four days has been reduced to two days in 1 of 24 experiments. The temperatures of the two days was as follows: maximum 105° F.; minimum 58° F.; and mean 81° F.

leaf beets or when allowed to puncture the bacteria into the tissue, rubbed on a portion of a beet leaf, failed to transmit the disease.

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NOTES ON THE CLIMATIC CONDITIONS INFLUENCING THE 1923 EPIDEMIC OF STEM RUST ON WHEAT IN ILLINOIS

L. R. Tehon and P. A. Young

With One Figure in the Text

Stem rust, caused by *Puccinia graminis* Pers., is prevalent in Illinois every season, but seldom in quantities sufficient to influence seriously the wheat yield of the state. The importance of this disease in more northerly situated states has, however, led to extensive epidemiological studies on the origin and spread of northern and southern infections.

The backward spring of 1923 with its attendant unusual weather provided conditions which appear to have been unusually suitable for the development of stem rust in Illinois. The development of the rust was kept under observation by the field workers of the Natural History Survey from the date of its first known appearance until the harvesting of the crop. Pertinent observations are presented here in connection with climatological data for the purpose of pointing out the influence of temperature and moisture in the development of an epidemic extending over a wide area.

Stem rust was first seen on wheat, June 4, in a 20-acre field of Red Wave located in the northwest corner of Jackson County. A single culm was found infected. Rust pustules on this culm occupied 50 per cent of the possible maximum culm surface (by the scale of U. S. Office of Cereal Investigations). The infected culm was located well in from the edge of the field.

On June 7 a few isolated groups of rusted culms were found in an 80-acre field of Fulcaster in Bond County. On these culms the rust pustules occupied 70 per cent of the possible maximum. A similar condition was seen June 12 in a 10-acre field of Fulz in Franklin County, and on June 14 two fields were seen, one in Hamilton and one in White County, where culms showed respectively 80 per cent and 100 per cent pustule involvement.

It is typical of these early observations that only a very few culms in any one spot showed infection, and that these foci were located well within the field, were well isolated from each other, and showed uniformly high percentages of pustule involvement. All observable facts pointed to the conclusion that these were primary infections of recent development.

There is no definite information as to the source of the inoculum for these infections. In the case of the first observation, four shrubs of common barberry were located 6 rods from the field, but a careful examination revealed no aecia. It may be supposed that the inoculum was furnished by uredinia overwintering in the field or on grasses along the roads or fence lines. The possibility of uredospores blowing up from the southwest or of aecidiospores traveling from the north is limited by the fact that the prevailing wind direction in this region during the month of May and during early June was easterly.

Beginning June 16, dissemination of the rust from original foci of infection became apparent. On that date infection on all culms within a small area in each of three 10-acre fields of Fulz was observed in Randolph County. On June 18, thirteen fields in Monroe County including about 160 acres showed isolated spots of rust infection comprising a number of plants and having areas of pustule involvement varying from 5 to 50 per cent, the lesser percentages apparently being infections produced by uredospores shed from the stalks showing higher degrees of pustule involvement.

By June 22 the per cent of infected plants generally had become nearly 100, but the original foci of infection could still be definitely located. Six fields in Morgan County showed large spots of infection with pustule involvement on the edges of 5 per cent, and toward the center of 35 per cent. Another field showed a general infection with an average pustule involvement of 10 per cent but with occasional spots of 70 per cent. On the 23rd in Adams County and on the 27th in Calhoun County similar conditions were seen.

The foregoing examples typify the progress of rust development as seen in other localities. In general, it appears that small and isolated foci of severe rust infection developed as a result of the presence of infectious material whose source was not determinable. Invariably these foci were severe infections showing large percentages of pustule involvement. From these foci, by degrees, the infection of entire fields was accomplished, the secondary and succeeding infections being gradually less severe and exhibiting correspondingly smaller percentages of pustule involvement.

The lessened severity of secondary infections may be attributed in part to the increasing maturity of the wheat plants (Stakman, E. C. and F. J. Piemeisel. Biologic forms of Puccinia graminis on cereals and grasses. Jour. Agr. Res. **10**: 431–432. 1917).

Moisture as a factor in the development of primary infections is im-

portant and under field conditions the necessary presence of moisture is definitely related to precipitation. There is an apparent relation between periods of precipitation (U. S. Weather Bureau, Climatological data for Illinois) and the occurrence of the infections recorded above.

For ten days previous to the finding of the first infection of the season in Jackson County, there had been rain in that district on all but one day. Obviously, the total amount of rain for the ten-day period is not important, but the fact that measurable amounts were recorded on seven of the ten days and an observable amount on two other days is indicative of the existence of moisture conditions suitable for spore germination and host infection throughout practically the whole of that period.

In the case of the primary infection in Bond County, during thirteen days previous rain had fallen on all but three days and for a period of nine consecutive days there had been an appreciable amount each day. These nine days were followed by three days of no rain and a fourth day of hard rain, none of which may be considered to have influenced the inception of the infection. Favorable moisture conditions in this and the previous case coincide rather definitely as to dates.

Although the infections in Franklin, Hamilton and White Counties were found five and seven days later than the above their appearance characterizes them as similar to the first two found. No certainty as to the date infection took place obtains, but it is reasonable to point out that, during the period of precipitations noted in the first two counties, smaller quantities had fallen in the last three counties, over a shorter and generally earlier period. The seven days immediately previous to the finding of the infection in Franklin County had, however, been initiated with precipitations over three consecutive days sufficient in amount to provide favorable conditions for spore germination.

When favorable moisture conditions obtain, there must exist at the same time proper temperatures for spore germinations and host infection. A comparison of temperature (maximum and minimum) and precipitation previous to the date of the finding of the infections is given in the following tables and discussions.

The first primary infection found (Jackson County, June 4) affords the best opportunity for speculation as to the influence of climate on the inception and development of infection. The attendant weather conditions were as follows:

	May 25	26	27	28	29	30	31	June 1	2	3	4
Precipitation	.08	.03	.02	.08	.02	T		T	.4	.02	
Temperature	74	74	82	87	86	87	88	83	85	86	87
	61	60	61	60	61	61	62	64	65	63	63

The ten-day period of rain previous to the finding of this infection was initiated by two days of unusually low maximum temperature. On the third day there was an increase in maximum temperature of eight degrees and on the fourth of five more degrees. This high maximum temperature was maintained with fair constancy during the remaining seven days. During the entire period the minimum temperature was fairly constant.

When the time necessary for development of infection is considered it is not likely that either the moisture or temperature during the last four days could have influenced infection. The first two days with their low temperatures were probably not conducive to spore germination. This leaves a period beginning May 27 and ending May 31 during which germination and infection could have taken place. The mean temperature on May 27 was 71.5° or an increase of 4.5° over the mean temperature of the day preceding. On the 28th the mean temperature of 73.5° represents a further increase of 2°. The average mean temperature for the five days from May 27 to May 31 was 73.5° and the greatest departure of the mean on any one day below this average was 2° while the greatest departure above was 1.5°.

The climatological conditions attending a thirteen-day period previous to the finding of the second primary infection (Bond County, June 7) coincide generally both as to points of time and conditions with those attending the first primary infection, as may be observed from an inspection of the following:

	May 25	26	27	28	29	30	31	June 1	2	3	4	5	6	7
Precipitation	.13	.11	.10	.40	.17	.16	.06	T	.82	0	0	0	.71	0
Temperature	73	74	76	72	77	80	81	77	82	83	84	80	—	81
	58	62	61	63	64	63	62	65	67	63	64	68	66	63

There was, however, generally a greater amount of precipitation, and, from the fifth to the thirteenth day preceding, no day passed without some precipitation. The first five days were characterized by rather low maximum temperatures. On the sixth day the maximum temperature rose 3° and was maintained at this point or above on all but one of the succeeding days. The minimum temperature was fairly constant throughout the period, averaging 63.5°. The greatest departure above the minimum average was 3.5° and below 5.5°. The average departure above was 2° and below 1.6°.

On May 30 the mean temperature was 71.5°, showing an increase of 1° over the day previous and of 3.5° over the average mean temperature for the five preceding days. During the five days from May 30 to June 3

the average mean temperature was 72.3°. The greatest departure of the mean above on any one day was 2.2° and below 1.3°.

A noteworthy coincidence is found in the fact that a mean temperature of 71.5° occurred in Bond County three days after it had occurred in Jackson County and that the first primary infection was found in Bond County three days after the first infection was found in Jackson County. Any significance that may be attached to this coincidence of elapsed time must find its justification in the fact that men were examining wheat fields in these two regions for several days before stem rust infections were found. The coincidence of a mean temperature of 71.5° may be considered as indicating the probable optimum for infection under field conditions.

The primary infection found in Franklin, Hamilton and White Counties must be considered in connection with the same climatological data since the point nearest to the infections where climatological data was recorded is at McLeansboro in Hamilton County. The consideration of these infections is further complicated by the fact that they were found in the first fields visited in those counties. The date of finding probably is not the date of first appearance. However, a consideration of the precipitation and temperature may serve to indicate when spore germination and host infection might have taken place. The McLeansboro records are as follows:

May						25	26	27	28	29	30	31
Precipitation						.18	.03	.17	.07		.24	.17
Temperature						73	75	79	81	86	84	88
						64	60	62	68	61	63	63
June	1	2	3	4	5	6	7	8	9	10	11	12
Precipitation					.03	.41	.04			.76	2.55	.12
Temperature	85	88	90	90	90	84	87	80	75	70	79	74
	64	64	62	62	65	66	64	57	56	58	66	61

Because of the uncertainty involved in the field observations as to the exact age of the rust pustules found in these counties, the data given above are shown from May 25 in order to furnish precipitation and temperature records covering the same days in this region as in the regions hitherto spoken of. The need for this is emphasized by the fact that all these infections lie in approximate relation so far as latitude is concerned.

The first three days of this period were initiated with comparatively low maximum temperatures, and an average mean temperature of 68.8°. The maximum temperature during the five following days was notice-

ably higher, ranging from 81° to 88°, and with a correspondingly higher average mean temperature of 74.3°. During this entire period there was sufficient precipitation to provide moisture conditions favorable for spore germination, although a comparison with the other regions shows that in these cases the precipitation was more spasmodic though greater in quantity.

It is impossible to surmise in any satisfactory way as to the influence of this period upon the inception of infection in this territory. It is, however, noteworthy that from June 5 to June 7 there was precipitation on each day. This period was preceded by four days and followed by two days when no precipitation fell. The maximum temperature during these three days of precipitation ranged from 84° to 90°, and the average mean temperature was 76°. The beginning of this rainy period was just seven days prior to the finding of the rust infection in Franklin County, and is comparable to eight days in the case of the Jackson and Bond County infections.

An inspection of the data on precipitation and temperature accompanying secondary and later infections observed in ten counties appears in general to conform with the above observations on the primary infections; and it may be seen that excellent conditions for the development of secondary and later infection were provided from time to time and in general over periods corresponding rather definitely as to dates, yet allowing sufficient latitude to account for later occurrence of infection and varying degrees of infection in the several instances.

The first observations of the occurrence of evident secondary infection (in Randolph County, June 16) was preceded by the following moisture and temperature conditions:

June	9	10	11	12	13	14	15	16
Precipitation	.45	.36	.87	.01			.44	
Temperature	80	71	81	74	88	91	81	85
	58	59	67	62	55	57	63	62

On each of the four days from June 9 to 12 precipitation fell and very likely provided favorable moisture conditions. On the 9th and again on the 11th the maximum temperature rose to 80° or above and on the 11th the mean temperature was 74°.

It may be seen that favorable conditions for spore germination and host infection both as to moisture and temperature occurred from five to seven days previous to the finding of the secondary infection.

This condition is duplicated generally in the case of the nine other counties in which observations were made. Under the presumption

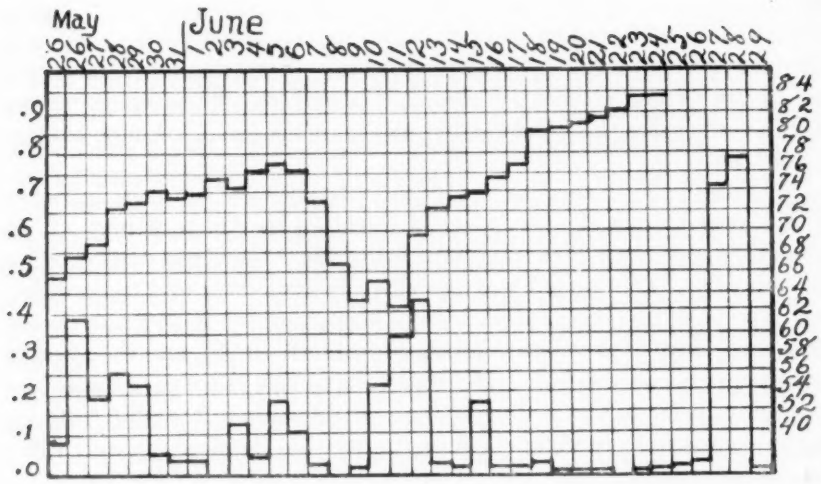

FIG. 1. Average mean temperature and average precipitation in fifteen counties of central and southern Illinois during late May and June.

Upper line: Average mean temperature. Temperature scale at the right.

Lower line: Average precipitation. Precipitation scale at the left.

that primary infection occurred in all cases either from about May 25 to 29 or June 2 to 6, subsequent periods of favorable spore-germination conditions may be considered as accounting for subsequent infections, whether secondary or later. The following chart showing precipitation and temperature summarized for the whole set of observations and the time when infections were found, will indicate, in terms of the above interpretations, the probable period of primary, secondary and later infections so far as they may be thought to have any dependence upon climatological conditions.

NOTES ON CRANBERRY FUNGI IN MASSACHUSETTS

NEIL E. STEVENS

The rots of cranberries (*Vaccinium macrocarpum*) caused by various fungi show, with but one or two exceptions, no constantly marked and characteristic differences. In order to determine the causal organism with any degree of accuracy it is necessary to make cultures from the tissues of the rotten berries. In the course of the studies of cranberry diseases[1] made under the general direction of Dr. C. L. Shear more than six thousand cultures from Massachusetts berries alone have fruited and been identified. These cultures have been largely incidental to the work on the diseases of cranberries carried on jointly by the Massachusetts Agricultural Experiment Station and the United States Bureau of Plant Industry. Over five thousand of these cultures have been made since the fall of 1916, at which time attention was directed especially to the rots which develop after the berries are picked. During this period much of the culture work has been handled during different seasons by Miss A. M. Beckwith, Miss M. S. Wilcox, B. A. Rudolph, Robert Jordan, and W. H. Sawyer, Jr. The storage and shipping experiments have been planned and carried out jointly by Dr. H. J. Franklin, Superintendent of the Cranberry substation at East Wareham, and the writer. Dr. Franklin has at all times placed the facilities of the state cranberry bog and laboratory at the disposal of those engaged in the mycological work, with the result that the data available are drawn largely from the region within twenty miles of East Wareham, and may not exactly represent the Massachusetts cranberry area as a whole. Notwithstanding this limitation, the work here summarized represents a more intensive study of the fungi causing decay than has been made of any other berry, and may thus justify brief presentation.

RELATIVE IMPORTANCE OF DIFFERENT ROT FUNGI

Fungi belonging to at least twenty-five genera have been found in cultures from decayed or sound cranberries. They differ greatly, however, in their relative abundance. Several fungi have been isolated only once or twice, while more than one-third of the berries from which cultures were made yielded the end-rot fungus, *Fusicoccum putrefaciens*.

[1] Cranberry diseases and their control. U. S. Dept. Agric., Farmers' Bulletin 1081, 1920, (and earlier papers by the same author).

In table 1 are listed the fungi which have been found more than ten times in the tissue of rotten or immature cranberries from Massachusetts, with the number of times they have occurred in the total of 6617 cultures which were identified. The second column gives the number of times each fungus has occurred in the cultures made from the tissue of rotten berries, while the third column gives the number of times each has occurred in the series of cultures made from freshly picked, immature berries.

TABLE 1—*More important fungi found in tissue of decayed cranberries from Massachusetts 1910 to 1922, and of green berries 1921 to 1923.*

Name of fungus	Number of times found in 5412 cultures from decayed berries.	Number of times found in 1205 cultures from green berries.
Fusicoccum putrefaciens Shear (causing end-rot)	2209	108
Glomerella cingulata vaccinii Shear. (causing bitter-rot)	1323	126
Phomopsis sp.	762	19
Sporonema oxycocci Shear	312	16
Guignardia vaccinii Shear (causing early-rot)	225	202
Penicillium sps.	204	183
Dematium sp.	158	225
Pestalozzia guepini vaccinii Shear	97	54
Acanthorhynchus vaccinii Shear (causing blotch-rot)	45	10
Alternaria sp.	15	159

In comparing the figures given in table 1, it should be borne in mind that the results of work on decayed berries cover a period of fourteen years and involve over five thousand cultures, whereas the work on green berries, which will be discussed in greater detail later, involves only about twelve hundred berries and is confined to the last three years. The results, however, plainly indicate that fungi of several genera, such as Dematium and Alternaria, are of more frequent occurrence in green berries on the vines than their importance as storage rots would seem to indicate. The high number of Penicillium cultures may well be due, in part, to contaminations.

EFFECT OF STORAGE TEMPERATURES ON THE DEVELOPMENT OF DIFFERENT FUNGI

While the data given in column 2 of table 1 may be taken as indicating the relative importance of the different fungi under average storage

conditions in Massachusetts it is evident that their abundance in any given case varies greatly and depends to some extent on the storage temperature. The effect of storage temperature is clearly shown by tests carried out in the fall of 1921 and 1922. In each test about a peck of sound berries from each of three different bogs were carefully sorted out by hand. This sample was then divided into two equal parts, one of which was stored in a ventilated crate at a temperature of approximately 0° C. while the other was stored in a similar container at a temperature varying from 15° C. to 20° C. In both seasons the storage test began in October and lasted four months. The results are given in table 2.

TABLE 2—*More important fungi found in berries which had decayed during temperature storage tests, expressed as per cent of total spoiled berries from which cultures were made.*

Name of fungus	Developed in storage at 0° C.	Developed in storage at 15°–20° C.
Fusicoccum putrefaciens	55.4	34.8
Glomerella cingulata vaccinii	2.0	14.0
Guignardia vaccinii	0.3	8.0
Acanthorhynchus vaccinii	0	3.7
Sterile	20.8	7.4

It is evident from these tests that the growth of *Fusicoccum putrefaciens* is not inhibited at temperatures near zero centigrade while the growth of such common rot fungi as *Guignardia vaccinii* and *Acanthorhynchus vaccinii* is practically stopped. Such a result might have been anticipated from their temperature relations as determined in pure culture.

TIME OF DEVELOPMENT OF FUNGI IN STORAGE

The difference in the temperature relations of the various rot fungi does not seem to account for the fact, demonstrated by Rudolph and Franklin[1] that different rot fungi tend to develop at different times in storage. In this careful piece of work it was clearly shown that under the conditions of the experiment in 1916 and 1917 such fungi as *Glomerella cingulata* and *Phomopsis sp.* predominated among those berries which decayed during the early part of the storage season while *Fusicoccum putrefaciens* was by far the most abundant organism in those berries which decayed later in the season. This relation held even though the

[1] Relative prevalence of fungi causing rots of cranberries at different periods during the storage season. Mass. Exp. Station Bul. 198: 88–92. 1920.

berries were stored at a uniform temperature of 20° C. The delay in the development of these fungi is all the harder to explain in view of the fact, demonstrated by the culture work of the last three years, that infection by these storage rot fungi often occurs early in the development of the berry.

TIME OF INFECTION OF CRANBERRIES BY FUNGI

That the rot producing fungi are either actually in the berry or so closely attached as not to be removed or injured by severe sterilization seems to be clearly demonstrated by series of cultures made in Massachusetts during the summers of 1921, 1922 and 1923. This work, which was planned to obtain information as to the prevalence and distribution of fungi on green berries, was carried out as follows. Beginning as early in July as the petals were shed, twenty or more berries were selected every week from each of several bogs and sterilized by soaking in a 1 to 1000 solution of mercuric-bichloride in seventy per cent alcohol, for five to ten minutes and then washing in sterile distilled water. They were then placed in sterile tubes of corn meal agar and held at room temperature.

The outstanding results of this work are that a large portion of the berries were found to be infected early in the season, that the proportion of infected berries did not increase greatly as the season advanced, and that most of the important fungi, even those that develop late, were found to be present early in the season. These results, which are summarised in tables 3 and 4, should be considered as applying only to the region and for the years in which the work was done.

TABLE 3—*Earliest dates on which various important rot fungi were found in green cranberries*[1] *in Massachusetts.*

Name of fungus	1921	1922	1923
Fusicoccum putrefaciens	July 13	July 6	July 18
Glomerella cingulata vaccinii	" 16	" 12	
Phomopsis sp.	August 2	" 6	
Sporonema oxycocci	July 21	" 6	July 19
Guignardia vaccinii	" 26	" 6	" 12
Penicillium sps.	" 13	" 6	" 11
Dematium sp.	" 13	" 6	" 11
Pestalozzia guepini vaccinii	" 16	" 12	" 19
Acanthorhynchus vaccinii	" 26		
Alternaria sp.	" 13	" 6	" 18

[1] In explanation of the difference in the time of appearance of the fungi it should be stated that the spring of 1922 was unusually early and warm.

TABLE 4—*Number of immature cranberries from which fungi developed in culture, expressed as per cent of total number of berries cultured.*

Date 1922	Per cent infected	Date 1923	Per cent infected
July 6	60		
" 12	48		
" 19	33	July 18	35
" 26	61	" 25	48
August 2	51	August 1	70
" 9	56	" 8	81
" 15	64	" 15	56
" 23	45	" 22	48
" 29	61		

PLACE OF INFECTION

A series of cultures made during 1922 and 1923 by sterilizing berries as described above and then cutting them in half with a sterile scalpel and culturing the halves separately shows, as might be expected, that the blossom end of the berry is much more likely to be infected by fungi than the stem end. Of a total of 150 berries cultured in 1922, 100 of the stem ends were sterile and only 53 of the blossom ends. In 1923 berries were sterilized and the stem and blossom ends cut off with a sterile scalpel. The three parts of the berry were then cultured separately. Out of a total of 120 such cultures, fungi developed from 55 per cent of the blossom ends, while fungi developed from only 12 per cent of the stem ends and middle portions.

Such fungi as Alternaria, Dematium and Fusicoccum were decidedly more abundant on the blossom end, while Guignardia was equally abundant in cultures from either end. In one case three different fungi were isolated from the blossom end of a single berry.

OCCURRENCE OF FUNGI IN DIFFERENT VARIETIES

Most of the culture work in Massachusetts has been done on the two principal commercial varieties of that region, Early Blacks, and Howes. All the fungi listed in the tables have been found on both these varieties, and most of them have been found also on McFarlins and Centenials.

DISTRIBUTION OF CRANBERRY ROT FUNGI BY FLOODING WATER

The injury to cranberry buds and blossoms which has occasionally occurred in Massachusetts during the June reflow led to a study of the

fungi found on cranberry buds and tips with special reference to the conditions before and after the vines were submerged. So far as relates to flooding injury the results have been negative. While, as might be expected, fungi are present on buds that have been injured by flooding, the fungi are not markedly more abundant, nor of different kinds than are found on normal flowers which have survived the flooding. Fungi apparently play little if any part in the so called "water injury."

These culture studies have, however, brought out the fact that the flooding water acts as a carrier of fungous spores, probably by bringing them up from the trash on the bottom or about the sides of the bog. The evidence on this point was secured by collecting tips bearing flower buds from various bogs just before the June reflow, and placing them on sterile culture media after sterilizing as described for the berries. As soon as possible after the flowage water was removed a similar set was taken from near the same place and treated in the same way. The results are given in table 5.

TABLE 5—*Results of cultures from cranberry tips taken before and after the June reflow. Averages of cultures from four different bogs each season.*

Year	Per cent infected by fungi before flooding	Per cent infected by fungi aft r flooding
1922	35	67
1923	14	77

That the results of 1923 are more striking than those of 1922 is perhaps due in part to the fact that the technique used was somewhat improved, and in part to the cold spring of 1923. That the difference between the first set of cultures and the second in both years is directly due to the effect of the flooding water seems to be proven by the fact that no such difference is found in tips taken at similar periods from bogs which have not been reflowed.

OCCURRENCE OF THE SAME FUNGI IN OTHER CRANBERRY GROWING SECTIONS

While it should be clearly understood that the data here presented are derived wholly from observations made in Massachusetts and the conclusions apply only to that region, the fungi are widely distributed. Some of them have been found, not only in the region of commercial cranberry culture where they might easily have been carried in shipments of vines, but outside those areas on wild vines. Of the fungi listed in table 1, *Fusicoccum putrefaciens*, *Acanthorhynchus vaccinii*, and

Phomopsis sp. have been found in New Jersey, Wisconsin, the cranberry region of the Pacific Coast, in Maine, and in North Carolina. *Glomerella cingulata vaccinii*, *Guignardia vaccinii*, *Dematium sp.* and *Pestalozzia guepini vaccinii* have been found in New Jersey, Wisconsin, on the Pacific Coast, and in North Carolina. *Sporonema oxycocci* has been found in New Jersey, Wisconsin, on the Pacific Coast, and in Maine; and *Alternaria sp.* and *Penicillium sps.* in New Jersey, Wisconsin, and on the Pacific Coast. *F. putrefaciens* and *A. vaccinii* have also been collected in Alaska on *Vaccinium oxycoccus* and *V. Vitis-Idaea*.

CROP INJURY RESULTING FROM MAGNESIUM OXIDE DUST

F. J. Sievers

With One Figure in the Text

Magnesium carbonate, when properly treated, finds, besides its many other uses in the industries, a strong demand as a lining for furnaces where basic ores are smelted. Large deposits of native magnesite, $MgCO_3$, are found in central Europe and these furnished most of our supply before the war. When, however, during the war an embargo was declared on this European product, there was an immediate interest in developing our own previously discovered magnesite resources. In eastern Washington is located a large deposit of magnesite rock of a very high percentage purity and this was mined, processed in newly constructed roasters and put on the market. In the manufacturing process the original rock is finely ground and mixed with a small amount of iron oxide and then calcined, resulting in a granular product referred to on the market as "dead burn" magnesite. This calcining is carried on at about 3900° F. in slightly inclined revolving cylindrical furnaces that are fed at the base with pulverized coal for fuel, with the result that much of the finely ground material after having been converted by this intense heat into the form of magnesium oxide is carried out through the stacks together with the smoke and large volumes of carbon dioxide gas, later to become deposited as a layer on the surrounding agricultural land. Due to the vigorous operation of the plant induced by wartime pressure although active only for a few years, the deposition of dust was sufficient to have a pronounced effect on the development of agricultural crops grown on soil in close proximity. At the time the plant discontinued operation a few years ago, this deposit, with its greatest thickness of somewhat more than an inch near the plant, was sufficiently extensive to be easily evident at distances of one and one-half miles to leeward.

The roaster is located in a valley bounded on the east and west by comparatively prominent mountain ranges and, due to the influence of this topography on the direction of air currents, even though located in the region of the prevailing westerlies, leeward here is both north and south of the source of the dust. With the magnesite plant as a center, the area over which crops were detrimentally affected was in the shape of an oval having approximately one mile and three miles, respectively, as its short and long axis.

The precipitation in this comparatively level, fertile and low lying valley, drained by the Colville River meandering through it, is limited to an average of about eighteen inches per annum, but this moisture supply is supplemented by sub-irrigation and surface run off from the surrounding uplands, which receive a slightly heavier annual rainfall. There has been little opportunity for loss of plant food through leaching, and consequently the soils contain large amounts of soluble salts, in some cases enough so that there were slight evidences of alkali, and practically all soils in the area were alkaline in reaction before the magnesite plant began operations. This alkalinity, being slight in amount or intensity, caused sufficient concentration of the soil solution to have a beneficial effect in the soil's productiveness. Soon after this deposition of magnesium oxide dust took place, however, injurious effects were noticeable on the crops. This was to be expected when one realizes that the deposited magnesia dust although only slightly soluble tended soon to increase the concentration of the soil solution or at least increase its toxicity to a point where it was no longer optimum for crop production. There apparently was a physical as well as a chemical, and no doubt also a pronounced toxic effect. The crust that accumulated on lands close to the plant from the time winter wheat was seeded up to the time that the plants should have appeared above the ground was of the consistency of mortar and sufficiently thick and impervious to make penetration by most plants impossible. The shoots that failed to penetrate this crust became elongated to a point where the energy in the seed was expended and then the plants died. Those plants that did get through soon took on a brownish yellow coloration at the tips of the leaves, and upon close examination it developed that consistent with plant conditions commonly found on alkali soil, practically their entire root system had been killed or corroded to the extent that there was no longer sufficient contact with the soil to furnish the necessary plant food or the foothold essential to hold the plants erect. Furthermore it is a common experience that within the injured area the detrimental effect of the magnesium is not nearly as pronounced in the early part of the growing season when the soil contains a high percentage of moisture and the soil solution is less concentrated. Various attempts to grow the small grain or grass crops to which this region is best adapted, failed for several years, and these failures were and are still decidedly pronounced close to the plant even after attempts had been made to overcome the difficulty by soil treatment with fertilizers, amendments and also irrigation water. At the distance of a mile or more, where there was still evidence

of the deposit, the injury was never as pronounced nor was it felt for as long a period. In some cases along the margin of the injured area where the deposit was only slight, it seemed to have even a beneficial effect on plant growth in which respect the conditions were similar to those ordinarily surrounding an alkali spot in irrigated regions.

To obtain all detailed information having a definite bearing on this subject, because of its importance to the magnesite industry and its relation to the use of magnesium carbonate or other compounds containing magnesium for soil treatment, a thorough investigation was planned by the author.

Field conditions were thoroughly examined and a record made of the influence of magnesium on plant development. Analyses for magnesium were made of representative soil samples carefully selected at various distances from the plant, soil from the area under consideration was taken to the plant house, where plants were grown on it under controlled conditions, and a fairly complete history of cropping experiences in the field was maintained.

The field area affected is quite diversified as regards soil type. It is comparatively common to find peat and muck adjacent to heavy silt or clayey loam. In such cases the crop injury from the magnesium deposit was always most pronounced on the peat and muck soils, which, because of their high organic matter content, were always lighter in volume weight. The difference in volume weight, which varied all the way from one million to three and a half million pounds per acre foot, has, no doubt, a decided bearing on the effect of magnesium, because on a percentage basis, even where the deposit was uniform, the concentration per unit of volume of soil in one case will be three and one-half times as great as in the other. This condition was taken into consideration in all chemical analyses of soil and subsoil and all results were calculated on the basis of pounds per acre foot before an attempt was made to analyze the data. Sixty-two field samples of both surface and subsoil were taken of the area affected two years after the plant had discontinued operation. The magnesium content was calculated on the basis of oxide, although it is recognized that little of it remains in that form after it reaches the soil. When the dust first leaves the stacks it is largely of an impalpable, amorphous nature and, with the exception of small amounts of unoxidized carbon and of uncalcined magnesium carbonate carried out with it, is composed almost entirely of magnesium in the oxide form. After it comes in contact with the soil and is exposed to the carbon dioxide of the air and to moisture it is soon converted into a comparatively stable

basic magnesium carbonate [(4 $MgCO_3$. $Mg(OH)_2$. 5 H_2O) and (3 $MgCO_3$. $Mg(OH)_2$. 3 H_2O)]. The magnesium carbonate although not readily soluble in water acts quite differently in a soil solution containing carbon dioxide where the more soluble bicarbonate is readily formed ($MgCO_3 + H_2O + CO_2 \rightarrow Mg\,H_2(CO_3)_2$. This reaction, in part, no doubt is also responsible for the fact that the toxic effect of the magnesium was most pronounced on soil high in organic matter or in soil where there was an opportunity for large amounts of carbon dioxide to be evolved.

It was found that although quite variable in its composition the normal surface soil contained about 4000 pounds of magnesium, calculated as oxide, per acre foot, while none of the samples, with possibly one exception, taken at a distance of one and a half miles from the plant and to leeward of it, contained 5000 pounds per acre foot. This amount increased toward the source of the dust, and as high as 56,000 pounds of magnesium oxide per acre foot were found within 100 feet of the plant. The subsoils of all samples were comparatively uniform in magnesium content irrespective of proximity to the plant. The average of all subsoil analyses shows about 5000 pounds of magnesium oxide per acre foot, or an amount slightly higher than for normal surface soil. It is not surprising to find a higher magnesium content in the normal subsoil because it is natural for all soluble substances in the soil to be carried downward. A sample of residual soil taken from within three feet above the magnesite rock at the mine supported splendid vegetation, and showed no higher magnesium content than is found in average productive soils. The fact, however, that the difference in composition between surface and subsoil is so slight, was of value to show that the magnesium deposit on the surface of these soils did not originate with the subsoil as a result of a "rise of alkali" as was somewhat generally contended by those who were not willing to acknowledge that the injury originated with the calcining plant.

To determine without question whether magnesium was either directly or indirectly responsible for the crop injury, soils from the fields surrounding the magnesite plant were collected and transferred to the greenhouse in an attempt to grow plants under controlled conditions. The samples of soil were taken from several locations at a distance of (1) 40 rods north, (2) 160 rods south, and 640 rods south of the calcining plant. These samples were then thoroughly mixed and two flowering pots were filled with each sample, so that each pot contained about 1000 grams of air dry soil. In each case one of these pots was left untreated,

and to the other, five grams of chemically pure magnesium carbonate ($MgCo_3$) were added and thoroughly mixed with it. Oats were planted and at the end of ten weeks the results represented in figure 1 were obtained.

The oats on the untreated soil taken at a distance of 40 rods from the plant all sprouted, but showed much the same brownish-yellow and generally sickly and stunted characteristics that were noted in the field.

FIG. 1. The effect on plant development of magnesia dust deposited on agricultural land as a result of eminations from the stacks of a magnesite calciner. Soils at 40 rods from the calciner were injured so decidedly that crops failed without any further application of magnesium carbonate. Soils from a distance of two miles were not affected and could even withstand an application of five grams of magnesium carbonate per 1000 grams of soil in addition to the deposit in the field without any pronounced sign of injury. On soils at a distance of 160 rods the injury, although noticeable, had not reached a maximum and the addition of magnesium carbonate in the pot aggravated the effect very greatly.

There was little difference between results from the untreated and the treated soil taken at this distance from the source of the dust, both were failures and the addition of more magnesium carbonate could cause no further injury. On the untreated soil from a distance of 160 rods from the source of the dust, the oats, although still discolored, sickly and stunted, were in much better condition than those on the treated soil which showed that the injurious effect here had not yet reached a maximum.

The treated soil taken at a distance of 160 rods from the source of the dust produced a crop failure and in this respect was comparable to th$_e$

untreated soil taken at a distance of 40 rods as previously discussed. Soil from a distance of two miles produced good oats under both conditions, although those on the untreated soil were slightly better than on the treated. This shows conclusively that magnesium, when present in soils beyond certain amounts, produced injurious effects on this cereal, and that the normal soil in this valley in localities where it is outside the zone of influence from the calcining plant does not carry enough magnesium or alkali salts to cause injury to crops.

All of the land in this valley is being intensively tilled, and since the calciner discontinued operations, the farmer, in his efforts to bring the dust-injured soils back into producing condition, has, through plowing, caused the magnesite deposit to become thoroughly distributed through a comparatively large soil volume. This has caused much of the crust to disappear and has made for a less concentrated soil solution at the immediate surface of the ground with the result that there is no longer such pronounced physical and chemical injury to the crops, and the injured area is gradually decreasing in size. Just how long it will take before the entire area is reclaimed under conditions where future deposition of dust is prevented is a matter of time and climate conditions, as they influence soil moisture during the growing season, but it is quite evident that the present injurious condition is not of a permanent nature.

WASHINGTON AGRICULTURAL EXPERIMENT STATION.

A CHEMICAL AND PATHOLOGICAL STUDY OF DECAY OF THE XYLEM OF THE APPLE CAUSED BY POLYSTICTUS VERSICOLOR FR.

R. G. SMITH[1]

This paper includes two proximate chemical analyses, the first of normal apple wood (*Pyrus malus* L.), the second of the same wood but altered in composition as a result of fungus attack (*Polystictus versicolor* Fr.) and in addition the proximate composition of equal volumes of the different woods with a proximate composition of the difference in weight of the two volumes.

LITERATURE

The author found a paucity of literature on the subject of complete wood analysis, less on the subject of wood analysis altered by fungus activity. Recent published articles of a physiological nature including chemical analyses are Tottingham (10) et al. on the composition of apple spurs and adjacent wood with special reference to the hemicellulose fraction, Butler (1) et al. on the proximate composition of different aged branches, trunk and roots of the apple tree at successive stages from spring dormancy to leaf fall. Hooker (6) made analyses of apple spurs including determinations of the true starch, at successive dates throughout the year. Articles dealing with the chemical aspect of wood analysis are confined to the special fractions, with the exception of the published papers of Dore (2–5). He has collected scattered methods, revised and improved analytical processes. Schorger (9) published an article defining the fractions of wood analysis.

PREPARATION OF MATERIAL

The xylem of an apple tree branch five years old partly altered as a result of fungus attack (*Polystictus versicolor* Fr.) was used for purpose of analysis. Identification was confirmed by Prof. W. T. Horne of the Dept. of Plant Pathology, University of California. The fungus altered wood was carefully removed with a knife and ground in a drug mill so that the powdered mass of wood passed through a sieve having

[1] The above work was carried on in the Div. of Plant Nutrition, University of California, under the direction of Prof. W. H. Dore.

The author wishes to express his appreciation for the suggestions and assistance given him.

50 meshes to the linear inch. The unaltered wood was obtained seven inches below the altered area in the direction of the trunk by repeated cross-sectional cuts (made with a cross-cut saw having 13 teeth to the inch) until the quantity of sawdust amounted to about 100 grms. The sawdust was ground and sieved the same as the altered.

ANALYTICAL METHODS

Moisture was determined by drying 2 grm. samples to constant weight at 100° C. Benzene extract was determined by extracting 2 grm. samples of the dried material in a Soxhlet apparatus for continuous extraction for 6 hrs. with benzene. The solvent was then evaporated and the residual extract dried for 1 hour at 100° C. and weighed.

Alcohol extract.—The residue from the benzene extraction was treated the same as above except 95 per cent alcohol was used as a solvent. The alcohol was evaporated off and the residue dried and weighed.

The alcohol soluble.—Sugars were determined by extracting two grms. samples in a Soxhlet apparatus for six hours with 80 c.c. of 95 per cent alcohol. The extract was evaporated to 10 c.c. taken up with boiling water, cooled, cleared with basic lead acetate deleaded with 10 per cent sodium carbonate filter washed, acidified with acetic acid made to volume and reducing sugars determined by Munson-Walker method (8). Reducing sugars as dextrose subtracted from alcohol extractive gives the non-sugars in the alcohol extract.

Starch.—This was determined by the taka-diatose method on the residue from benzene and alcohol extraction after gelatinising with 100 c.c. boiling water. The resulting maltose and dextrins were hydrolysed into dextrose and the amount determined by Munson and Walker's (8) method and calculated as starch.

Hemicellulose.—The residue from the starch determination was made up to volume of 100 c.c. one per cent hydrochloric acid and hydrolysed over a steam bath for three hours, filtered. The filtrate was boiled, neutralized with solid lead carbonate, filtered and washed, made to volume, and acidified with acetic acid. Reducing sugars determined by Munson-Walker (8) results converted to hexosan formula. Pentosan in the hemicellulose fraction were determined by taking aliquot proportions of above volume and distilling with 12 per cent hydrochloric acid (Krober method) (7) and calculating the yield of phloroglucid to pentosan sugar by Krober table (7). The pentosan weight was subtracted from the total hexosan and remainder expressed as hexosan. Cellulose was

determined by successive chlorinations after extracting with benzene and alcohol according to the method of Dore (3).

The residue from cellulose determination was distilled with 12 per cent hydrochloric acid (Krober method) (7) and the yield of phloroglucid calculated to pentosan (Krober table) (7). The pentosan weight was subtracted from the total cellulose and the remainder expressed as pentosan-free cellulose. Lignin was determined after extraction with benzene and alcohol according to Dore (3).

SPECIFIC GRAVITY DETERMINATION

The specific gravity of the unaltered and the altered wood was determined accurately by aid of the analytical balance. Cubic pieces of wood were taken from the altered area, and similar pieces of unaltered wood from seven inches below the altered area and directly opposite the altered area. All were dried to constant weight at 100° C., weighed, covered with paraffin by means of a camels hair brush and reweighed, then weighed held under water in a 50 c.c. breaker, on the pan of the analytical balance, by a slender steel needle. The weight of the paraffin covering cubes determined also its sp. gr. and the volume of water displaced by it subtracted from the volume displaced by combined volume of the paraffin covered wood. From this data the sp. gr. of the wood cube was determined.

FRACTIONS OF ANALYSIS DEFINED

In a complex organic substance of the nature of wood it is impossible to isolate completely the individual complexes of its formation; in our present state of knowledge the complexes are broken up into fractions which form the units of analysis. The following are the fractions used in this analysis and their content. Benzene alcohol extractive fractions are composed of fats, dyes, proteins, ethereal oil, resins and soluble reducing sugars, starch fraction, of starch. Hemicellulose fraction in the apple is regarded by Tottingham et al. (10) to be composed of hexosan and pentosan sugars identified by them as glucose, xylose and galactose. The above are considered by Schorger (9) to be the secondary constituents of wood, the main constituent being the lignocellulose complex, which is broken into the cellulose and lignin fractions. The cellulose fraction is defined by Dore (3) as a product prepared by processes of sufficient intensity to remove all extractives (resins, dyes, etc.), incrusting substances (lignin) and hemicelluloses (condensed carbohydrates of pentose, manose, glucose, and galactos basis), and limited in

their action to these bodies. It may contain A–B–and Y cellulose (mercerisation test) also furfural yielding complexes. Schorger's definition of the lignin fraction is "lignins are characterized as being carbohydrate derivatives containing methyl methoxyl, formyl and acetyl groups and consequently have a higher carbon content than cellulose or the hemicelluloses."

RESULTS OF ANALYSES

All results of the proximate analysis of altered and unaltered apple wood are given in the following table, in addition the proximate composition of equal volumes of the different woods with a proximate composition of the difference in weight of the volumes.

TABLE 1—*Result of analysis of healthy and decayed apple wood.*

Explanation of lettered columns given below

		A	*B*	*AA*	*BB*	*C*	*D*
Benzene Ext.		.26	.55	.1638	.2420	+ .0782	+.32
Alcohol "	Alc. Sol. Sugars	1.36	1.34	.8568	.5896	— .2672	—31
	Non-sugars	2.94	.65	1.8522	.2860	—1.5662	—84
Starch		3.00	3.51	1.8900	1.5444	— .3456	—18
Hemicellulose	hexosans	4.54	3.08	2.8602	1.3552	—1.5050	—52
	pentosans	4.59	3.88	2.8917	1.7072	—1.1845	—40
Cellulose	pentosan-free	40.96	38.19	25.8048	16.8036	—9.0012	—34
	pentosan-in	14.05	8.24	8.8515	3.6256	—5.2259	—59
Lignin		25.09	35.96	15.8067	15.8224	+ .0157	+0.09
Undetermined		3.21	4.60	2.0223	2.0240	+ .0017	+0.08
		100.	100.	63 Grms.	44 Grms.	—19 Grms.	Per cent

Results of analysis given in columns A and B: A being figures for unaltered wood and B those for altered wood expressed in percentage on moisture free basis. These results show a decrease in all constituents except benzene extract, lignin and undetermined. Lignin shows a marked increase and since no new lignin can be assumed to have formed it would appear probable that the increase is due to concentration by removal of other constituents. This data in itself does not show that lignin remains unattacked but it does show that it is at least much less attacked than other constituents. Further light, however, is thrown upon this matter by calculation based upon the specific gravities of the two samples. Unaltered wood has an apparent sp. gr. (i. e., an average sp. gr. including air spaces) of .63, altered wood .44. Since the volume

of the wood is presumably not altered by the fungus attack we may assume that the material which is finally contained in 44 grms. is the residue remaining from 63 grms. of original material.

Accordingly the analyses have been recalculated to a comparable basis; that in column AA representing analysis A recalculated to a basis of 63 grms., that in column BB representing analysis B calculated to a basis of 44 grms.

A comparison of these figures shows the relative amounts of each constituent before and after fungus attack. The differences are given in column C and the percentage differences in column D.

The change in the amount of lignin is negligible and within the experimental error of the analysis. The results accordingly tend to indicate that lignin is unchanged. The differences in the undetermined constituents are likewise negligible. The increase in benzene extract may possibly be due to the accumulation of resinous by-products incidental to the fungus activity. All other constituents appear to be definitely attacked.

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ABSTRACTS OF PAPERS PRESENTED AT THE SEVENTH ANNUAL MEETING OF THE PACIFIC DIVISION OF THE AMERICAN PHYTOPATHOLOGICAL SOCIETY, LOS ANGELES, CALIFORNIA, SEPTEMBER 18 TO 21, 1923.

Mosaic and other systemic disorders of raspberries in the Pacific Northwest. S. M. ZELLER.
Effect of rougeing on spread of curly top in beets. E. C. TITUS.
Physiological specialization in Fomes Pinicola Fr. HENRY SCHMITZ.
American foreign plant quarantines. R. KENT BEATTIE.

SYMPOSIUM

Ecological factors influencing the distribution and severity of insect pests and plant diseases. Discussion lead by E. T. BARTHOLOMEW, H. J. WEBBER, H. S. FAWCETT, and H. H. P. SEVERIN.

This was a joint meeting with the Pacific Slope Branch of the American Association of Economic Entomologists, The Pacific Division of the Physiological Section of the Botanical Society of America, and the Ecological Society of America.

Decay of Douglas fir due to Poria incrassata. S. M. ZELLER.

Poria incrassata has been found to do rapid and extreme damage to Douglas fir structural timber and flooring when there is any contact with soil as a source of moisture. The spores germinate readily on damp soil or coniferous wood and rhizomorphs from 10–18 mm. diam. are formed leading to wood further from moisture supplies. The decay is brown and fragile.

Mosaic disease of loganberry. S. M. ZELLER.

Mosaic of loganberry is very destructive and widespread. Its present known range is from Sonoma County, California, to Snohomish County, Washington. In Oregon many 1 to 60 acre tracts have been grubbed out because of this disease. Nearly all younger plantings have from 3 to 95 per cent of the plants affected. Plants gradually decline and die out in 3 to 4 years after first symptoms appear.

Influence of time and temperature on the rate of growth of certain fungi. H. S. FAWCETT.

An experiment was performed in which the mycelia of two fungi (*Pythiacystis citrophthora* and *Diplodia natalensis* both citrus fruit rotting fungi) were allowed to advance continuously in large long class tubes for periods of four and six months in uniform medium with only the slightly fluctuating temperatures of a dark basement room. After a short initial adjustment, both fungi grew during the long periods of the experiments at average rates fluctuating along with the fluctuating temperatures. Neither of these fungi appeared to be affected by the time element in their ability to respond to a given temperature. For example *Diplodia natalensis* is an average temperature of 15.1° C. during the 7th week advanced 23 mm. This same average temperature was again recorded in the 19th and 21st weeks in each of which the fungus advanced just 24 mm. The increment of growth dropped to 18 mm. on the 8th week at 14.1° C. and the same drop took place on the 20th week at 14.4° C. With *Pythiacystis citrophthora* an average temperature of 15.5° C. occurring on the 4th and again on the 11th week was accompanied by a growth of 27 mm. in each case. There appeared therefore to be no evidence of "staling" or slowing down with the age of the culture under the

conditions of the experiment. The range of temperatures experienced during the 6 months were from 12.8° to 21.1° C. Other previous experiments with the same organisms showed that for shorter periods of from 3 to 6 days and especially for higher temperatures the time element had an important influence on rate of growth.

Alternaria rot of lemons. E. T. BARTHOLOMEW.

Losses due to Alternaria rot are encountered in all of the lemon-growing districts of California. The decay almost invariably begins at the button (calyx cup plus receptacle) end of the lemon, the fungus gaining entrance through or under the button. Experiments have shown that there is a certain amount of button infection at about the time the petals are withering. Whether the mycelium produced in the tissues at this time remains in a dormant or semi-dormant condition while the fruit is maturing and then develops and produces the decay or whether the decay is more directly due to later infection by spores which have lodged in the crevices of the button or between the button and the lemon has not been definitely determined. Under ordinary conditions the lemon fruit itself never becomes infected until it is mature and even then not until certain unknown physiological changes occur which permit the fungus to invade the tissues. The invasion of the lemon tissue under the button usually takes place while the lemons are in storage or transit but it may occur on the tree if the lemons are allowed to remain unpicked until over-ripe. No medium has yet been found which will sterilize the button tissues without injury to the fruit. Spraying experiments are being conducted in the groves but without the hope of much success because of the almost continuous blossoming and setting of new fruits in most of the lemon growing districts.

The study of resistance to crown-gall in Prunus. C. O. SMITH.

About forty different species and numerous varieties of Prunus have been tested for crown gall resistance, using artificial inoculations as a means of infection.

A great difference in susceptibility has been found. In some diversified species as *P. domestica,* susceptible and resistant varieties have been found. In other species the seedlings and varieties tested seem to indicate that the species itself show strong resistance. Certain of the evergreen species (*Laurocerasus*) have shown total resistance. The species that apparently have strong resistance are *P. pumila, P. Besseyi, P. Mume, P. umbellata, P. alleghaniensis, P. serotina, P. caroliniana, P. ilicifolia, P. tangutica* and some varieties of *P. domestica* and *P. insititia.*

The adaptability, under California conditions, of the resistant species, as stocks for the stone fruits is being tested. It is too soon to give conclusive results, but two species, *Prunus Mume* and *Prunus Besseyi* appear promising.

The resistant hosts of Prunus in many cases show a characteristic development of the hypertrophies. These are not typical subspherical galls, but are small in size, often cylindrical, mere point-like growths on the margins of the healing tissue. Many of them do not continue to develop and after a time disappear.

Effect of environmental conditions on western yellow blight of tomatoes. MICHAEL SHAPOVALOV.

The geographical distribution and the seasonal prevalence of western Yellow Blight of tomatoes depend primarily on climatic conditions. The disease tends to assume alarming proportions in localities and seasons characterized by a relatively high temperature, low humidity and high evaporation and is of little or no significance where

and when the humidity is high and the temperature and the evaporation are low. The rôle of climatic conditions in the development of Western Blight of tomatoes may be twofold: (1) direct upon the host predisposing the latter to the subsequent infection with parasitic or saprophytic organisms and (2) producing a set of conditions favoring aggressive activities of such organisms. There are clear indications as to the important effect of environments in bringing about the diseased conditions of the host aside fromt the interference of parasites. A progressive root decay has been invariably observed in connection with Western Tomato Blight. Several fungi, principally *Fusarium spp.* and *Rhizoctonia solani*, have been isolated from these decaying portions of the roots, but their exact rôle in the development of the complex symptoms of Western Blight has not been definitely determined. It is probable that a physiological collapse of small rootlets precede the fungus infection.

The behavior of certain varieties of tomato to the wilt disease (Fusarium) in California. M. SHAPOVALOV AND J. W. LESLEY.

The possibility of controlling tomato wilt by means of resistant varieties has been tested at three places in Southern California during 1923. Artificial inoculations with pure cultures of *Fusarium lycopersici* as well as naturally infected soils were used to test the behavior of different varieties. Consistent results were obtained. Stone and San Jose Canner proved to be highly susceptible. With the former variety as a control, Globe, Columbia and some selections made in California and tested for the first time showed a fair degree of resistance. Norton, Norduke, Marvel, Louisiana Red, Louisiana Pink, Illinois New Century and a few unnamed selections appeared to be very resistant. Several of these gave correspondingly good yields. Perhaps Norton was the most promising and is probably much superior to Stone for planting on soils infected with wilt Fusarium in California.

A disease of tomatoes caused by Phytophthora mexicana sp. nov. J. W. HOTSON AND LENA HARTGE.

This organism was isolated from tomatoes shipped into Seattle, Wash., from Mexico in the early summer of 1917. Cultural studies on artificial media, on the tomato plant and on the tomato fruit have shown it to be a species hitherto undescribed. This constitutes the fifth disease that has been reported on tomatoes in the United States and doubtless would become a serious pest if it once became established. The conidia ($16\text{–}33 \times 16\text{–}77\,\mu$) are produced abundantly and vary greatly in size and form. The oospores are large, the greater number of them measuring $37\,\mu$ in diameter Only a few of these were observed germinating in Van Tieghem cells.

Recent advances in dusting methods. RALPH E. SMITH.

Considerable difficulty has been experienced in the commercial preparation and handling of nicotine dust on account of the volatile nature of nicotine Nicotine dust is also very expensive in proportion to the content of essential ingredients. It also requires the preparation and handling by dealers of a variety of strengths and combinations in order to meet the various requirements. The idea of the self-mixing duster is to have a dusting machine with which the original materials, like nicotine, lime, lead arsenate, sulphur or dry Bordeaux mixture, may be placed in the hopper in any desired proportion and the mixing accomplished there in the same operation as that of dusting. Any dry, powdered materia may be used, also a liquid ke n cotine sulphate solution

when mixed with any dry carrier which will absorb the desired amount of liquid and still remain dusty Hydrated lime is the carrier commonly employed for making a plain nicotine dust. The mixing action of the self-duster is accomplished by putting an agitator into the hopper and passing the dust *through* the fan.

Immunity to mildew (Bremia lactucae Reg.) and its inheritance in lettuce. IVAN C. JAGGER.

A large number of varieties of lettuce have been tested and eight varieties found which seem entirely immune to mildew in both California and Florida. These varieties all appear to be of European origin and in general unsuited to American conditions. They have been hybridized with the popular variety Los Angeles Market or New York, which is sold on the markets as Iceberg lettuce. This variety is very susceptible to mildew. All first generation plants have been immune to mildew, and the few thousand second generation plants so far grown have given ratios which approximate three immune plants to one susceptible plant. Immunity seems to be inherited as a simple Mendelian dominant character. It is expected that hybridization and selection will give immune strains of the New York and other popular varieties of lettuce.

Bacterial slime disease of lettuce. RALPH E. SMITH AND ELIZABETH H. SMITH.

The growing of out-of-door lettuce for eastern and local shipment has increased very greatly in recent years. By the choice of different localities for different seasons it has been found possible to produce high quality lettuce practically throughout the entire year. The crop is grown in Imperial Valley during the winter, in various interior and coastward valleys in spring and early summer, and in certain very cool localities close to the coast during the summer and fall. In all these localities trouble is being experienced with a disease characterized mainly by a tip and edge burn of the leaves, running down into a slimy rot of the head. This causes serious losses in the field and in shipment and at times a demoralization of the industry. The disease usually first appears when the heads are just beginning to form and reaches its maximum development at the maturity of the crop. The occurrence of warm and humid weather appears to produce favorable conditions for infection. The universally grown "Los Angeles" variety is most susceptible. "Big Boston" and "Ice Berg" are less so. The trouble is of bacterial nature but has not yet been proven to be due to a single organism. It is similar to some of the diseases described by Brown.

Progress report on curly-top of the sugar beet. EUBANKS CARSNER AND C. F. STAHL.

The project of developing a strain of beets resistant to curly-top has received the most emphasis from the writers during the past several years. Beets apparently resistant have been selected from seriously affected commercial and experimental fields. Seed has been grown from these plants with precautions against cross pollination. The progeny has been tested by plantings at Riverside, California, where natural infestations of the beet leafhopper regularly occur and also by inoculating each individual plant by means of viriferous leafhoppers. In the fall of 1921, 2611 and in the summers of 1922 and 1923, respectively, 2269 and 4403 plants were thus inoculated. These numbers include the controls of commercial seed. Marked resistance has been noted in some strains. During the current season a considerable number of individual plants which were diseased in May or early June developed roots weighing 2 to 5 pounds. Plants from ordinary commercial seed usually die or produce only worthless roots if

infected so early. A serious handicap has been encountered in the tendency of some of the most promising strains to produce seed stalks the first season. This objectionable character is thought to result from climatic influences. If so, it can be overcome.

Results with *Chenopodium murale* are interesting in connection with the question of resistance to curly-top. All of our earlier inoculations of this species and most of those later have given negative results. In some cases, however, positive evidence that the plants contracted the disease has been obtained. A peculiar development in some of the positive cases indicates that by passage through this resistant plant the virus may be attenuated or modified.

A recent development of significance in the curly-top problem has been the production of the disease by artificial inoculation. This has been done by H. P. Severin. Subsequently it was accomplished by one of the writers. A few positive cases were obtained from a considerable number of trials by using expressed juice of diseased beets and also small pieces of diseased beet tissue. In view of this development there is more justification than formerly existed for classifying curly-top as a mosaic disease.

Curly leaf transmission experiments. HENRY H. P. SEVERIN.

Juice pressed from the leaves and roots of curly leaf beets when inoculated into the crown of healthy beets caused typical curly leaf symptoms in nine of one hundred beets. The period from the date of inoculation until the earliest symptom of curly leaf developed varied from 12 to 39 days. Non-infective beet leafhoppers, when allowed to feed on the inoculated beets after curly leaf developed, transmitted the disease to healthy beets, the earliest symptom appearing in from 2 to 13 days.

The shortest time required for the infective principle of curly leaf to travel through a beet petiole seven inches long was one-half hour at a mean temperature of 103.5° F. Infective beet leafhoppers were placed on a beet seedling feeding on the inner or youngest leaf, and at the same time non-infective males placed on one of the outer or oldest leaves became infective at the end of two days, as was proved by transferring them to a healthy beet. Similar results were obtained from one outer leaf to the opposite outer leaf and from one cotyledon to the outer leaf.

Infective beet leafhoppers retained their infectivity during all of the nymphal stages, after each molt, and during the entire adult life, as was demonstrated by supplying each insect with a healthy beet daily.

Mosaic and leaf roll of potatoes in Idaho. CHAS. W. HUNGERFORD AND J. M. RAEDER.

Mosaic and leaf roll are among the most important and destructive potato diseases in Idaho. There are at least three distinct types of mosaic in the state, each apparently distinct. The green and pink rose aphid is plentiful in the potato growing districts and experiments have shown that it may transmit the russet dwarf type of mosaic under Idaho conditions. Environmental conditions may influence the appearance of mosaic in any given seed lot. This may be due to masking of symptoms or to infection from local sources. The russet dwarf type of mosaic may appear as slight mottling late in the season soon after infection has taken place and progeny from such plants may develop very severe advanced stages of the disease. Primary symptoms of leaf roll may appear as slight rolling of the upper leaves late in the season on otherwise vigorous plants. Progeny from such plants may develop leaf roll in very advanced stages.

A root-rot and wilt of udo. J. L. WEIMER.

Two diseases of udo (*Aralia cordata* Thunb.) have been investigated. The roots of this plant are sometimes completely destroyed by a soft, wet rot. The infected tissues are permeated with hyphae, which soon form numerous black sclerotia within and on the surface of the decayed roots. No fruiting stage of the causal fungus has been seen but the mycelium and sclerotia appear to be those of *Sclerotinia libertiana* Fcl. The fungus has been isolated and its parasitism proved. The disease has also been produced by inoculating udo plants with *Sclerotinia libertiana* from pure authentic cultures.

The udo is also subject to a wilt disease caused by *Verticillium albo-atrum* R. & B. This disease resembles the wilts produced in other plants by the fungus. The causal fungus has been isolated from diseased udo plants and the disease produced by inoculations with it from pure cultures. The details of these investigations will be published in the Journal of Agricultural Research.

Investigative work on white pine blister rust in the Pacific Northwest for 1922. J. S. BOYCE.

The disease was probably introduced on the Pacific Coast in 1910 on a shipment of eastern white pines from Ussy, France, which were planted at Vancouver, British Columbia. It is now widespread in the coast region of British Columbia and Washington and has also been found at several places in eastern British Columbia.

Assuming Vancouver as the principal point of origin and the date of introduction as 1910, in 12 years the rust has extended over a triangle of country roughly 300 miles or more on a side.

Dry growing seasons retard the spread of the rust and wet seasons greatly accelerate the spread. All the western species of Ribes and Grossularia so far found in association with diseased pines are susceptible to infection although in varying degree. Western white pine is subject to very severe injury and it seems more susceptible than eastern white pine.

A new disease of cultivated barley in California caused by Helminthosporium californicum, n. sp. W. W. MACKIE AND G. E. PAXTON.

An undescribed species of Helminthosporium has been observed to be generally distributed and abundant in California on cultivated barley. Its period of development begins much later than that of other Helminthosporium species previously described. It appears with the warm, dry weather and develops rapidly. The apical ends of the leaves are first attacked and finally a "rusty blotch" is formed on the leaves. The lower leaves are first attacked and the disease progresses to the top of the plant. The grain is shriveled due to the premature death of the leaves. The spots are irregular, brown to bluish black, usually merging into diffused brownish discoloration of larger part of leaf. The spots are not netted (*H. t r:s*), elongated (*H. gramineum*), or definitely bounded dead areas (*H. sativum*). The conidia of *H. californicum*, n. sp., are dark olivaceous when fully mature; fusiform, not curved; thick walled; 40–85 μ × 20–26 μ; average 58 × 22 μ; 3–9 septate. Germinate by single germ tube from any segment. It resembles *H. sativum* P. K. & B. except that it occurs later, is more severe, the diseased areas are not definite and have no distinct margins. The conidia are longer, wider, more dense, thicker walled and not curved. The rusty blotch which has been observed for four years in California has been determined to be a new species of Helminthosporium and has been named **H. californicum**. It has been increasing in severity in the Sacramento and San Joaquin Valleys. Studies carried on show marked varietal resistance to this disease.

Some diseases new to California. E. H. SMITH.

The following diseases are reported as occurring in California, with brief discussion:

Kale, Cabbage, and flowering stock ..... Fusarium yellows.
Raspberry blue stem ..... (*Verticillium sp.*)
Sweet pea root rot ..... (*Thielavia basicola* [B. & Br.] Zopf.).
Wine grape fruit rot ..... (*Botrytis cinerea* Pers.).
Alfalfa stem Nematode ..... (*Tylenchus dipsaci* Kuhn.).
Asparagus leaf and stem spot ..... (*Cercospora sp.*).
Almond scab ..... (*Cladosporium carpophilum* Thum.).
Sunflower and Onion crown rot ..... (*Sclerotinia sps.*).
Sugar beet ..... (Rhizoctonia rot).
Watermelon leaf mildew ..... (*Peronoplasmopara cubensis* [B. & C.]).

PHYTOPATHOLOGICAL NOTES

Red plum curl (caused by Exoascus mirabilis Atk.). A serious disease of red plums was collected in southern Illinois by Dr. H. W. Anderson in 1920 and, in 1922 and 1923, field men working in the Illinois State Natural History Survey reported it from seventeen counties in the southern and central parts of the state. Usually ½–5 per cent of the twigs on infected trees are killed. The causal fungus was identified as *Exoascus mirabilis* Atk. (Bull. Torrey Bot. Club **21**: 376. 1894) by Miss Anna E. Jenkins of the Federal Office of Pathological Collections. Its macroscopic characteristics agree closely with those of the very similar *Exoascus decipiens* Atk. as pictured by Swingle and Morris (Mont. Agr. Exp. Sta. Circ. 77: Fig. 6. 1918). Infected leaves are partially or wholly distorted. They are greatly thickened and mostly unexpanded, merging imperceptibly into irregularly spatulate and greatly hypertrophied twigs. Infected twigs are green at first, later drying and becoming gray to black. Infected tissue resembles that of plum pockets and becomes brittle when mature and dry. Red plum curl is not of great economic importance in Illinois because no large quantity of plums is grown for the market here.—Paul A. Young.

On the names Sclerotinia sclerotiorum (Lib.) Massee, and S. libertiana Fuckel. Both in the United States and Europe there is a large and increasing volume of literature on this common and fairly omnivorous parasite, with, however, a discrepancy in nomenclature which seems to require explanation.

American papers, almost without exception, refer to the fungus as *Sclerotinia libertiana* Fuckel, and in the latest of these ("Taxonomy of the Sclerotinia on Helianthus annuus L." by Mrs. Seymour Jones, in Phytopathology XIII, Nov. 1923, p. 496), the name *S. sclerotiorum*, under which the fungus is generally known in this country, is definitely relegated to a subordinate place as a synonym of *S. libertiana*.

Enquiry into the history of the species shows at once, however, that the reverse is the case.

The fungus was distributed in 1837 by Madame Libert in her Pl. Crypt. Arduennae, Fasc. IV, No. 326. The name *Peziza sclerotiorum* was given to it, and was accompanied by a Latin description, the whole constituting perfectly valid publication. Fuckel in his Symbolae My-

cologicae (1869–70) transferred the species to his genus Sclerotinia, and at the same time changed the name to "*S. Libertiana*", presumably merely because he disliked the combination *S. sclerotiorum*. Fuckel left no doubt as to his plant, for he cited as synonyms *Peziza sclerotiorum* Libert and another name of his own, *P. Sclerotii* Fuckel.

Now this name-change by Fuckel is definitely contrary to the rule embodied in both the American Code and the International Rules of Nomenclature, and now generally accepted, namely, that when a species is transferred from one genus to another the original specific name is retained, unless the resulting combination is already preoccupied. In the case of *S. sclerotiorum* there was no such previous use of the combination, because Fuckel himself proposed the genus. Consequently according to all the rules of nomenclature at present accepted there is no justification for the perpetuation of Fuckel's name.

As a matter of fact nearly all other European workers have adopted Madame Libert's specific name. Gillet in 1879 called it *Phialea sclerotiorum*, and Phillips in 1887 put it in *Hymenoscypha* (sub-genus *Sclerotinia*) *sclerotiorum*. Boudier however adopted Fuckel's name.

The actual combination *Sclerotinia sclerotiorum* was apparently first used by Massee in Vol. IV of his British Fungus Flora (1895) and has been retained in all English pathological literature since.—ELSIE M. WAKEFIELD, (KEW).

H. Morstatt. Einführung in die Pflanzenpathologie. Pp. 157. 1923.

The book comprises a complete, though short treatise, of the subject of plant pathology, embracing, however, not only the study of phytopathology proper, but also of entomology in so far as the latter is related to the study of plant diseases. The work naturally divides itself into four parts: (a) symptomology, (b) aetiology, prognosis and diagnosis, (c) the causes of plant diseases, and (4) disease control. Under symptomology, the writer treats general disease manifestations such as: wilting, discoloration, necrosis, structural malformations, and outlines the procedure to be followed in the description and investigation of plant diseases. The second chapter, which is by far the most interesting assembles concisely, yet thoroughly much recent information on the nature of plant diseases, the significance of predisposition and immunity, the inheritance of resistance, and the contributions made by studies in pathological anatomy and physiology. The chapter on causes is a synopsis of disease producing bacteria, fungi and animal parasites. Under inanimate causes are considered the effects of unfavorable weather

and soil conditions, smoke, gas and spray injuries. The chapter on disease control recommends such practices as are generally employed in plant pest control in America. The book furnishes a valuable compilation of recent developments and views upon which progress in the science of plant pathology is being made. It will be useful to all students of the subject for its complete and authentic treatment of the principles of plant pathology.—ERNST ARTSCHWAGER.

Personals. The Department of Agriculture of Bermuda has appointed its first permanent Plant Pathologist, in the person of Mr. Lawrence Ogilvie. Mr. Ogilvie is a graduate of Aberdeen University, Scotland. He has done graduate work in Botany and Entomology in the University of Cambridge. I desire to enlist for Mr. Ogilvie the assistance and co-operation of American Plant Pathologists. Reprints, bulletins and other publications bearing on plant diseases will be especially helpful for this young Pathologist in his first position.—H. H. WHETZEL.

Dr. F. Dickson of Cornell University is assuming a position as Professor in the Department of Botany, University of British Columbia, Vancouver, B. C., Canada.

Dr. Arthur S. Rhoads, Pathologist of the Missouri State Fruit Experiment Station, has accepted the position of Assistant Plant Pathologist of the Florida Agricultural Experiment Station.

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